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Examining a Cumulative Risk Index for Language Delay in Infants at High- and Low-Risk for Autism

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EXAMINING A CUMULATIVE RISK INDEX FOR LANGUAGE DELAY IN INFANTS AT HIGH- AND LOW-RISK FOR AUTISM

by

NONYE A.O. NWOSU

Under the Direction of Elizabeth Tighe, PhD

ABSTRACT

The purpose of this study was to analyze secondary data collected from a sample of 173 mother-infant dyads comprised of infants at high- and low-risk for autism spectrum disorder (ASD) at 12 and 36 months of age. More specifically, the study assessed the predictive capacity of a cumulative risk index (CRI) of several maternal and child factors; risk is defined by eight factors: 1) infant sex, 2) receptive language, 3) expressive language, 4) autism symptomology, 4) social-communication, 5) gesture, 6) maternal depressive symptoms, and 7) maternal concerns for ASD, and their singular and cumulative predictive impact—moderated by group assignment—on later child language scores on the *Mullen Scales of Early Learning* (Mullen, 1995). Thirty-six children received a diagnosis of ASD, 31 of whom were at high-risk at 12 months. Risk at 12 months was predictive of receptive and expressive language at 36 months and resulted in increased likelihood of an ASD diagnosis at 36 months. The CRI, 12-month receptive language, and maternal concerns were significant, unique predictors of expressive language at 36 months. As well, the CRI, 12-month receptive language, and gesture were significant, unique predictors for likelihood of ASD diagnosis at 36 months. Children at high-risk for ASD displayed increased cumulative risk in early developmental domains compared to children at low-risk that may index prospective language outcomes. The implications of these findings and the burgeoning research in high-risk for ASD are discussed.

INDEX WORDS: Language development, Cumulative risk, High-risk, Infant siblings, Autism spectrum disorder, Parenting

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DEDICATION

I dedicate this document to my incredibly loving and supportive husband family. Thank you for continually motivating me throughout my graduate studies and especially towards the end when I needed you the most. Most importantly, I dedicate this to the Nnedis in my life, Nnedima Anya and Nnedinma Nwosu who have served me in inspiration and motivation through your resilience and perseverance in the face of tribulations.

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1 INTRODUCTION

Parents of children with developmental delays play a fundamental role in shaping their children′s development, amongst the unique challenges of raising children with special needs. The literature has recognized that these parents of children with autism spectrum disorder (ASD) report higher levels of caregiver burden and unique demands (e.g., increased time spent providing care and paying for medical services) when compared to parents of children with typical development (Benevides, Lee, Nwosu, & Franks, 2019; Blacher & Baker, 2007; Davis & Carter, 2008). Children with early language delays often have difficulty adequately communicating their needs, and thus having their needs met. This is especially true for children with ASD. Children with ASD exhibit core deficits in language and social-communication (Wetherby, Watt, Morgan, & Shumway, 2007; Yoder, Watson, Lambert, 2015) which have been shown to have long-ranging impacts on maternal behavior and dyadic interaction (Blacher, Baker, & Kaladjian, 2013), which provide the basis for language learning.

Early childhood is a sensitive period for development–impacted by both biology and environment. Variability in these factors may potentiate risk, which influences long-term outcomes. According to Michael Rutter–as cited by Evans, Whipple, and Li, 2013–while the majority of children are at least exposed to singular or additional risk factors and ultimately experience minimal long-term harm, if any, children exposed to multiple risk factors are more inclined to suffer from medical disorder. Moreover, Evans and colleagues (2013) noted that regardless of intercorrelation or independence among risk factors, cumulative (also known as multiple or multiplex) risk assessment better predicts distal outcomes than standard multiple regression. This can be expected given that ecological factors (e.g., home environment, parents and child, and parents′ work environment) interact to some degree to impact development (see Bronfenbrenner′s Ecological Model; Bronfenbrenner, 1994). Thus, numerous studies have examined the influence of multiple or cumulative risk (Bedford et al., 2014; Burchinal, Roberts, Hooper, & Zeisel, 2000; Campana, Lerner, & David, 2015; Hooper, Burchinal, Roberts, Zeisel, & Neebe, 1998; Shriver, Bonnell, Levi, & Camp, 2017; Wade, Browne, Plamondon, Daniel, & Jenkins, 2016) to examine the compounding effect of singular risk factors on development. As such, the current study also examined cumulative risk on language outcomes for infants at high- and low-risk for ASD. Children who have an elder sibling with ASD are considered high-risk due the increased likelihood (20%) of being diagnosed with ASD in the future. As well, parents of a child with ASD are also parents of children who are at high-risk for ASD.

Children with ASD are at increased risk for suboptimal language outcomes given the core deficits in social-communication (e.g., language) and behavior (e.g., decreased social engagement) intrinsic to the disorder that augment developmental delays and disrupt the developmental trajectory. They are less engaged during interaction with their caregivers (Adamson, Bakeman, Deckner, & Romski, 2009), which can lead them to tune-out during instances that would otherwise optimize social-communicative behaviors (Siller & Sigman, 2008). They also initiate and respond to joint attention (a critical component of communication and symbolic behavior and emerging language) bids less and more infrequently overall (Bono, Daley, & Sigman, 2004), which the literature suggests impacts language development and the parent-child relationship, and is central to the unique deficits seen in early ASD (Jones & Carr, 2004).

Schwichtenberg, Young, Sigman, Hutman, and Ozonoff (2010) noted that children at high-risk (i.e., defined as having an elder sibling diagnosed with ASD) display an amalgam of subclinical patterns of atypical or delayed behavior (e.g., joint engagement) similar to the social-communicative and behavioral patterns seen, specifically, in ASD (Ozonoff et al., 2014), known as the broader autism phenotype. High-risk siblings, similar to children with ASD, also perform lower overall on developmental assessment measures compared to their typically developing counterparts (Schwichtenberg et al., 2015), suggesting that they are also at heightened-risk for developmental delays, like language (Ozonoff et al., 2009). The researchers furthered that the features of the broader autism phenotype may resultantly index genetic risk for ASD, similar to Losh, Childress, Lam, & Piven (2008) who discussed the endophenotypic profile–heritable interplay of biological, physiological, and neurophysiological markers in the affected and unaffected–of ASD. These findings suggest that this population, ASD and high-risk, is unique to other groups with developmental disabilities and share commonalities that are largely unexplored but necessitate examination.

Collectively, this study intends to contribute to the growing research in maternal behavior, early development in ASD, and child language outcomes, but to also contribute to the burgeoning literature in studying high-risk infant siblings. The extant literature has recognized the need for models of cumulative risk (or multi-risk) to examine various factors of child and familial characteristics (Evans et al., 2013) to presently predict risk and prospectively predict outcomes (Burchinal et al., 2000). This study aggregated measures into a cumulative risk index (CRI) as a means to build a profile of risk to investigate the impact of maternal depression, self-reported concerns for development, and child characteristics in a mixed (high- and low-risk) sample of infants and predict language outcomes.

1.1 Language Development and Autism Spectrum Disorder

Language ability is a salient and significant indicator of delays − and a strong predictor of developmental outcomes − and is a well-examined factor in ASD and high-risk research. As such, language skill can be assessed reliably and is particularly useful in the information it provides for service providers like teachers and therapists (Tager-Flusberg et al., 2009). Language delay or oddities (i.e., echolalia or unusual cadence) are among the earliest indicators recognized by parents that propels them to seek medical help. Much of the early literature on language development of children with ASD–theoretical framework for high-risk–has called for greater recognition of language delays and provision for these individuals with access to intervention and therapeutic services. Tager-Flusberg, Paul, and Lord (2005) noted that recognizing individual differences in expressive language should not hinder recognition of delays in ASD, the idea being that providers may explain away delays as part of the natural heterogeneity in language development, and thus delay intervention. While it is important to guard against early perseveration on labeling, intervening as early as language delays are recognized and utilizing empirically based interventions that target developmental and behavioral components may have positive effects on language (for some), if not communication (for most).

Children with ASD and some of their siblings, experience increased difficulty comprehending and expressing themselves linguistically (Sullivan et al., 2007). These factors may have early and lasting effects on sharing and learning within dyadic interaction. For children with ASD or at increased risk for ASD, it is valuable for researchers to have a means to cohesively examine a reliable profile of language outcome risk for early intervention given the well-established and valid assessment measures. Thus, the primary purpose of this study is to cumulatively examine maternal (concerns and mental health) and child (communicative, linguistic, and cognitive development and autism severity) performance on numerous standardized measures for infants who are and are not at high-risk for ASD and what significance these risk factors may have on later child language outcomes. Previous research examining maternal depression and language has not concurrently included child-based factors, which are bidirectionally associated, warranting further examination to understand outcomes. Furthermore, examining the impact of cumulative risk from risk factors for language development may provide a deeper understanding of which specific risk factors may predict language outcomes in children at high-risk, and, more uniquely, how we can utilize gold-standard assessment measures to support this prediction of language risk for early intervention.

ASD is typically not formally diagnosed until children are nearly four years old (Richards, Mossey, & Robins, 2016), though the research literature has suggested that prodromal symptoms are seen within the first year of life, indicating a possibility for early detection and need for earlier intervention. Woods and Wetherby (2003) stipulated the urgency of early recognition in noting that intervention before age three is more impactful on developmental outcomes (language) than after age five.

Parents most often describe concerns or challenges in children's speech and language (Richards et al., 2016) followed by social behaviors (e.g., imitation and pretend play), which Herlihy, Knoch, Viberrt, and Fein (2015) noted are less predictive than communication concerns anyway. Accordingly, such challenges in language and socializing are the earliest indicators of language delay and atypical development (e.g., broader autism phenotype). In addition to the research literature establishing the vitality of language ability on proximal (e.g., communication) and distal (e.g., academic achievement) outcomes, parents consistently report concerns with language at the top of their list. This underscores not only the importance of language, but also its foundation across multiple dimensions of research. As well, prioritizing language development recognizes parents' reported concerns and needs, and may result in them being more motivated and active in early language interventions, endorsing the utility of maternal concerns as a measure in this study. Moreover, parents of children at high-risk, those who have an elder sibling with ASD, have displayed proficiency in how they actually describe and the extent of their concerns, likely given their experiences with their elder child with ASD in observing behavior and learning more about the unique characteristics and associated terminology related to ASD. Talbott, Nelson, and Tager-Flusberg (2015b) support this point; in their study of developmental concerns reported by mothers in weekly diaries that were kept when infants at high- and low-risk were 6 to 12 months of age, they found that mothers of infants at high-risk were significantly more inclined to report concerns about language, social communication, and restricted and repetitive behaviors, but were not in reporting general, medically based concerns. These findings are noteworthy given that siblings of children with ASD are at heightened risk of also being diagnosed with ASD over time.

1.2 Siblings of children with ASD

From research investigating children at high-risk for ASD (siblings of children with ASD), there is an estimated nearly 20% recurrence rate (Singer, 2017). That is, younger siblings of a child with ASD are 20% more likely to be diagnosed with ASD than children without elder siblings with ASD, which is a significantly greater risk than the general population. Landa and Garrett-Meyer (2006) reported that this is over 100 times the risk than the general population. Given the shared genetics and ASD's genetic/neurodevelopmental basis, it is conceivable that, as Ozonoff et al. (2009) stated, early development in high-risk siblings may be similarly atypical *regardless* of eventual ASD diagnosis. The descriptor "broad autism phenotype" points to an expanded physical profile that encompasses core traits (e.g., atypical expressive language, socialization, and pragmatics), but is not ASD, that is far and above seen in family members of individuals with ASD that do not have ASD themselves (Losh, Childress, Lam, & Piven, 2008), especially high-risk siblings.

In their early years of life, children with ASD orient less to their name and are less intrigued by social stimuli – like the sound of their mother's voice or other voices – as compared to children with developmental disabilities or typically developing children (Tager-Flusberg et al., 2005). Additionally, the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013) denotes that poor and infrequent eye contact may also be a sign of ASD, which has been recognized as a sign of ASD in the literature (Wetherby et al., 2007; Shumway & Wetherby, 2009). Similarly, high-risk siblings also are less reactive towards social stimuli and display poorer joint attention and engagement, suggesting that like their siblings, early patterns of atypical development affecting social-communication are present (Kasari et al., 2014; Parladé & Iverson,2015). This has prompted researchers, who have since emphasized the importance of early diagnosis and intervention, to invest more energy in targeting and understanding this group to better inform intervention and monitoring.

Herlihy and colleagues (2015) recruited a mixed sample of 61 toddlers (high-risk = 21; low-risk = 27; only or eldest child = 21) and found that children scored similarly in receptive language on the MSEL (M_{age} = 25.6 months); however, they scored significantly differently on the expressive and visual-reception subscales. Children at high-risk demonstrated the highest mean scores and the children with no siblings group received the lowest scores; children at low-risk did not differ significantly from either group. Using the MSEL, LeBarton & Iverson (2016) found that for children at high-risk with no outcome diagnosis and those with language delay, they had similar receptive and expressive language scores, with higher receptive than expressive scores. Children at high-risk eventually diagnosed with ASD scored significantly lower in receptive and expressive compared to the two, and conversely had higher expressive than receptive scores. Iverson et al. (2018) indicated that differences between receptive and expressive language scores are complex to interpret, especially for parents, as the direct observation permitted by production of words and gestures may be more salient than inferring child's early comprehension. Similarly, researchers have noted inconsistent findings in studying very early receptive and expressive language largely due to heterogeneity in the language development process. Nevertheless, it is a critical component of early and later child language.

The current study is unique in that it capitalizes on the longitudinal nature of the extant data with a high-risk population to assess a number of early maternal and child characteristics on later child language outcomes that have not been considered concurrently. Additionally, the widespread reliance on standardized assessment measures as integral to the research process is clear from their centrality in the studies examined; numerous well-examined and gold-standard assessment measures were included in the current study. Twelve months (and often no earlier) is an age where parents and clinicians can see clearer intentionality in children's behavior (as seen by the validity in parent concerns on ASD status at 36 months), so it is appropriate to use to examine early predictive factors on later development. Researchers (Bedford et al., 2014; Rowberry et al., 2015; Sacrey et al., 2015;2018b) have examined predictors at 12 months and 36 month outcomes to understand early predictive factors on child development (Szatmari et al., 2016).

1.3 Modeling Risk in Child Development

Risk has long been studied across child development (Bronfenbrenner, 1986; Hooper et al., 1998; Shriver, Bonnell, & Camp, 2017) to further understand the factors that influence individual differences, growth, and outcomes. Risk refers to a position that, while not always predictive of adverse outcomes, can indicate states (e.g., development, socioeconomic status, and health) or deficits (e.g., domains of functioning) in areas that heighten the likelihood of undesirable outcomes (Evans et al., 2013). Researchers have employed varying methods to examine what constitutes risk and how to measure risk and its influence on outcomes. Researchers study risk to explain outcomes in cognition (Wade et al., 2016), socio-behavioral development (e.g., attachment and joint engagement), academic achievement, physical health, communication, and language (Boin Choi, Shaw, Rowe, Nelson, & Tager-Flusberg, 2019; Talbott, Nelson, & Tager-Flusberg, 2015a). Variables that have often been examined in these contexts include (Evans et al., 2013) cognition (e.g., global developmental delays and brain activity; Hooper et al., 1998), sociodemographic measures (e.g., parental education, sex, and racial/ethnic diversity; Bronfenbrenner, 1986), physical health markers (e.g., motoric behavior and growth charts), communication and symbolic behavior (e.g., joint attention and imitation; Sullivan et al., 2007), and verbal and nonverbal language (e.g., gesture and expressive and receptive language; Özçalışkan, Adamson, Dimitrova, & Baumann, 2017).

According to Evans et al. (2013), cumulative risk assessment is the most widely studied among multiple (cumulative) risk (i.e., CR) models of development. As well, they stated that with all its promise, there have been few examinations in CR literature comparing the strengths and weaknesses of this approach and how it compares to the standard method of assessing additive models of individual risk (using regressions for analyses). The authors state that most often CR studies establish a theoretically driven metric for ascertaining risk cut-offs, then dichotomize the variables of study, and aggregate the given score for each variable to yield a single CR score. This, they state, is a parsimonious and replicable way to study increased likelihood for undesirable outcomes. They juxtapose CR models to the other common method, standard multiple regression. In their meta-analysis, Evans and colleagues (2013) examined 95 cumulative risk studies across all areas of child development; they found that in 58 of the studies CR did not fare as well as additive, nonaggregated (e.g., singular risk factors) methods of risk assessment, but state that numerous studies did not provide necessary data for comparability.

Altogether, suggesting that both CR and individual risk variable models are empirically-supported means of risk assessment.

Burchinal et al. (2000) conducted a prospective, longitudinal study of cumulative risk on child cognitive and language development in 87 African-American, mother-child dyads. They examined maternal and environmental, sociodemographic factors, including maternal education, depression, marital status, and responsiveness in addition to SES, household size, stressful life events, respite, and home environment at 12, 24, 36, and 48 months. Innovatively, they compared three methods of multi-risk assessment: 1) CRI, 2) additive, singular risk model, and 3) a summary risk-factor scores model (three latent constructs with multiple measured factors). They found that the additive, singular factor model better predicted concurrent outcomes pertinent to developmental age (overall developmental level), the summary risk-factor model was well-suited for predicting developmental patterns, and the CRI was better at prospectively predicting developmental patterns from risk; all observed relations between risk and outcomes. These studies provided a strong theoretical framework for the current study in illuminating how to build risk models, but also the importance of sound methodology to comparably examine best methods of risk assessment.

High-risk children by definition are not guaranteed to have ASD, but are considered high-risk because of the increased likelihood of future ASD diagnosis, and due to aspects of their phenotypic profile (i.e., social-communication and behavior) that are known to index maladaptive outcomes. Each of the factors used in the current study were intentionally chosen because of their established place in the child development literature through numerous examinations of validity and reliability and their use in research and clinical settings, especially for high-risk and ASD. The factors in the current study include both adult and child characteristics. Zwaigenbaum and colleagues (2009) cited the MSEL, CSBS, and CDI as current gold-standard methods of assessment for numerous domains of child development. Thus, utilizing a cumulative risk index (CRI) for language to provide a reliable means of screening in combination with gold-standard assessment measures would provide a streamlined method for detecting young children who are in need of language intervention.

1.4 Cumulative Risk

Cumulative risk refers to an individual's experience with or endorsement of numerous factors established to be associated with more negative outcomes (Evans et al., 2013). Within the broader literature cumulative or multi-risk has been used to examine children's characteristics and current skills in addition to their microecology (e.g., maternal-child interaction) and exosystems (e.g., socioeconomic status) to predict future outcomes like cognitive development. Evans et al. (2013) posits that such work is done to assess the role of singular risk factors on development, but no consensus of cumulative risk exists despite its utility in research and public policy. Burchinal and colleagues (2000; Hooper et al., 1998) are one of the few developmental researchers to examine the effects of cumulative risk on language *and* cognition. As noted, language is a crucial predictor of outcomes in academic achievement and quality of life, and an indicator of disorder (e.g., autism and specific language impairment). Manwaring, Stevens, Mowdood, and Lackey (2018) highlighted the critical role of gesture in language in addition to noting the atypical early gesture development profile in high-risk and ASD; moreover, the designation of atypical gesture as a DSM-5 criterion for ASD. Taken together, this suggests that verbal and nonverbal language in addition to factors impacting language are consequential for examining cumulative risk, especially in siblings of children with ASD (high-risk).

Risk assessment is critical, especially in early childhood, because it can be a joint first step in diagnosis which paves the way for intervention. Tager-Flusberg (2016) implored the field to examine cumulative risk to not only single out risk factors, but to study how they converge on child development. This may promote further understanding of how to tailor treatment types and dosage to maximally enhance gains from language intervention for children. For example, noting a multiplicative effect of risk in early expressive and receptive language and gesture but not behavior on later language may suggest an intervention targeting language and social-communication versus the Early Start Denver Model (ESDM; Dawson et al., 2010) a comprehensive early behavioral intervention, may be more impactful.

While risk is often assessed using standardized measures, the current study is the first time a cumulative risk approach has been utilized in predicting language outcomes in a high-risk sample. Indexing standardized measures, reporting, and personal characteristics has not yet been examined to ascertain risk nor to predict outcomes. This is a valuable method of assessment because it has the potential for generalizability as these are methods that have been notably employed separately or some in conjunction with other methods (Paul, Norbury, and Gosse, 2017; Talbott et al., 2015a; 2015b). Chambers and colleagues (2017) remarked on the significant strides made in early detection and intervention. Given the clear consensus in the referenced literature that the earliest intervention is imperative, we are tasked with identifying easily replicable and generalizable methods of risk assessment in parsimonious manners. Keeping this in mind, the CRI for this study was cultivated by choosing well-established singular factors of risk for language development detailed below. These factors include: 1) child sex, 2) receptive language, 3) expressive language, 4) ASD symptomology, 5) social-communication, 6) gesture,

7) maternal depressive symptoms, and 8) maternal concerns. Each factor is described in detail below.

1.4.1 Child Sex

Scientific research (Rubenstein, Wiggins, & Lee, 2014) and the Autism and Developmental Disabilities Monitoring Network (ADDM)—the authority on surveillance of developmental disabilities prevalence and incidence estimates—has established that boys are four times more likely than girls to be diagnosed with ASD (Baio et al., 2018), and this discrepancy has remained constant from the earliest examinations of ASD (Zwaigenbaum et al., 2012).

Additionally, developmental research (Harwood, Miller, & Vasta, 2008; Özçalışkan & Goldin-Meadow, 2010) has acknowledged early differences in verbal and nonverbal ability, that is girls produce language (i.e., sentences) earlier than boys, have larger vocabularies early on, and begin gesturing earlier. Moreover, Harwood and colleagues (2008) stated that boys are more likely to be diagnosed with speech and language disabilities, which they suggest may be due to the effects of testosterone on brain lateralization. Additionally, differences in the socialization of behavior—largely from caregivers—from the earliest periods of childhood coupled with these established biological differences suggest that differences in language ability exist between males and females. Therefore, sex is considered a risk factor for the current CRI given its recognition in the literature on the early and long-term differences observed in language between males and females.

1.4.2 Receptive and Expressive Language

Language development is a relatively heterogeneous process. Numerous studies have identified language skill as a pervasive symptom of delay or disorder (Lord, Shulman, DiLavore, 2004; Tager-

Flusberg et al., 2005; Wetherby & Prizant, 2001). As well, the extant literature has noted that developmentally appropriate language skill at five is significantly associated with long-term quality of life outcomes in language fluency and academic (Adamson et al., 2009; Adamson, Kaiser, Tamis-LeMonda, Owen, & Dimitrova, 2014; Bono et al., 2004; Lord, Risi, & Pickles, 2004; Tager-Flusberg et al., 2005, 2009; Wetherby & Prizant, 2001) and vocational achievement (Tager-Flusberg et al., 2016). Understandably, early language abilities established in infancy (as early as 12 months) can provide a foundation for concurrent abilities or delays that may carry on over time. Thus, it is a variable sensitive to early intervention for better quality of life.

The fluency and flexibility of language use is a very important predictor of quality of life outcomes and level of impairment in ASD (i.e., high vs. low functioning). Lord and colleagues (2004) remarked on the significance of language skill by noting that it remains a significant predictor of language outcomes whether measured by spontaneous language samples, parent-report (e.g., *MacArthur Communicative Development Inventory*; CDI, Fenson et al., 2007), standardized measures (e.g. *Mullen Scales of Early Learning*; MSEL, Mullen, 1995), or more advanced methods of measuring syntax (e.g. via coding or Language Environment Analysis; LENA). Thus, language skill is an integral factor when we examine ASD and seek to provide treatment. Language (receptive and expressive) was chosen as the central outcome measure in this study because it is predicted by a number of prerequisite factors (e.g., developmental level, parent-child dynamic, and medical status), and 12-month language was considered a risk factor of later language outcomes as it provides an index of early language abilities. Reports on the expressive and receptive language in infants at high- and low-risk have been conflicting, Toth, Dawson, Meltzoff, Greenson, and Fein (2007) noted that numerous studies have reported finding significant differences in both early (as young as 14 months) and later (up to 36 months) language, but there is incongruence in predicting expressive versus receptive. Moreover, one study no longer found significant differences between the children at high- and low-risk by 54 months (Toth et al., 2007). In a number of studies, some of these children, mostly siblings at high-risk, receive ASD diagnoses which may also explain poorer language outcomes (Landa & Garrett, 2006; Toth et al., 2007).

At 12 months, infants' ability to produce language is fairly limited, they can comprehend more than they can express, but barring any severe cognitive impairment, at this point infants seem to be fairly similar in their comprehension levels. By 18 months, vocabulary explosion has them rapidly learning new words and expanding their lexicon (Maljaar, Noens, Scholte, & van Berckelaer-Onnes, 2012; Rescorla, 2011) thus, it is conceivable that the divergence in expressive language ability may take off at this point, furthering any discrepancies in ability between those with language delays and without. This supports Woods and Wetherby's (2003) claim stipulating that intervention before age three is more impactful than after. Sullivan et al. (2007) noted varying degrees of language difficulty are intrinsic to the broad autism phenotype (high-risk siblings), so it remains to be seen over time whether children at high-risk will remain or converge on the typical trajectory of language development or not.

The *Mullen Scales of Early Learning* (MSEL; Mullen, 1995) is one of the most widely used norm-referenced assessments of child development. It provides a comprehensive measure of early development, and is often used to assess children with developmental disabilities (Mullen, 1995). The MSEL tests cognition (verbal and non-verbal skill) and motor ability; there are five subscales: Motor- fine and gross; Visual receptive organization; Language- expressive and receptive (Cronbach's $\alpha_{\text{average}} = .78$). Scores in any of the domains are intended to yield information about the child's level of skill in the respective areas. As such, an early learning composite can be derived by aggregating scores from the domains to obtain an overall assessment of developmental level. For the current study, receptive and expressive language T scores were used to index language ability, separately. As well, fine and gross motor T scores, nonverbal language measures, were used to control for overall developmental level. Therefore, early MSEL receptive and expressive language scores at 12 months are considered a risk factor for the current CRI given its long-standing establishment as a reliable, gold-standard measure of development, especially in children with developmental disabilities and delays.

1.4.3 ASD symptomology

A greater number of high-risk siblings are said to show "subclinical" levels (the broad autism phenotype) of atypical behaviors with or without eventual ASD diagnoses (Kjelgaard & Tager-Flusberg, 2001; Schwichtenberg, Young, Sigman, Hutman, & Ozonoff, 2010; Szatmari et al., 2016). Ozonoff et al. (2009) reports that nearly 50% of children at high-risk exhibit atypical development. Differences are first seen in children at high-risk′s social-communicative behavior.

Early joint attention is an early indicator of social-communicative behavior and can provide red flags regarding atypical development and, especially, ASD symptoms. Children with ASD show persistent deficits in joint attention and engagement which impact language (Bono et al., 2004; McDuffie & Yoder, 2010. Bottema-Beutel (2016) conducted a meta-analysis of studies that evaluated the association between joint attention and language in children with ASD and typical development (TD) (M_{ASD} = 24 months; M_{TD} = 16 months). She found that children with ASD had significantly impaired joint attention skills across reports compared to children with TD. She speculated that joint attention seemed to be more strongly associated to language outcomes for children with ASD than children with TD, who typically present with age-appropriate joint attention ability, thus joint attention may not account for greater variation in their language development, which is already impaired in young children with ASD and at high-risk.

Within the literature, it has been clearly stipulated that parents of children at high-risk are more likely to not only have concerns about their child′s development, but to also share concerns specific to ASD, described with specific ASD symptomology (or terminology) which specifically describe social-communication concerns that eventually relate to language, like diminished joint attention. Across categorized groups of children (high- and low-risk, and high-risk with or without ASD) certain behavioral signs are described in the first year of life, with Herlihy et al. (2015) noting that prodromal symptoms can be seen in the domains of social and regulatory behavior as early as three to six months and social attentiveness by six months. These differences extend to other social domains (e.g., social smiling and vocalizing) distinctly by 12 months (Herlihy et al., 2015); thus, the prevalent focus on examining parent concerns by 12 months and later ASD outcomes. This all stresses the importance of early intervention based on early patterns of atypical development with possible long-term effects on language (Boin Choi et al., 2019).

The *Autism Observation Scale for Infants* (AOSI; Bryson, McDermott, Rombough, Brian, & Zwaigenbaum, 2000) is a rating scale that was created especially for infants at high-risk to detect and assess early signs of behavior related to ASD (Bryson, Zwaigenbaum, McDermott, Rombough, & Brian, 2008). Additionally, the AOSI is one of few measures that is developmentally appropriate for both infants and children at high-risk. The AOSI was used in the original study as a marker of ASD symptomology for the infants, and was also used in the current study as such when the infants were 12 months. Some of the behaviors assessed by the

AOSI include: joint attention and engagement, imitation, behavioral sensitivity, early social-affective and communicative behaviors, and numerous sensory-motor behaviors (Bryson et al., 2008). Most of these behaviors index early social-communication patterns: Intrinsically, these are hallmark behaviors where deficits are noted in ASD, so they provide a benchmark for the examination of ASD symptomology. Higher AOSI scores mean a higher level of ASD behaviors which are known to disrupt early language learning, and language learning is dependent upon healthy social-interaction with more advanced social partners that facilitate language acquisition over time.

Franchini et al. (2018) found associations between AOSI scores, gesture development, and diagnostic outcomes in their study of developmental skills at 6 months onto outcomes between 9 to 24 months in high-risk children with ASD. Gammer et al. (2015), Sacrey et al. (2018b), and Yaari et al. (2016) included the AOSI in their research, but reported lower predictive power in ASD diagnosis. Although this information is conflicting, it warrants inclusion in this study because it is a measure specifically created for children at high-risk that has been utilized in research. Examining the AOSI as an index for social-communication and language outcomes, the central focus of the current study, rather than diagnostic outcome, may further exploration of its' predictive power. Thus, ASD symptomology is examined as a risk factor in the current CRI given its specificity in providing an index for level of ASD symptoms and social-communication in children at high-risk, who comprise a large majority of the current study.

1.4.4 Social-Communication

Within the broad autism phenotype (children at high-risk who have an elder sibling with ASD), a marked area of deficits and early concern from parents is in social-communication, impacting both non-verbal communication (i.e., social norms like the use of gesture and facial expressions) and the development of and long-term use of language. The broad autism phenotype denotes deficits that are similar in presentation to ASD, but is not clinically ASD. Tager-Flusberg (2016) noted that the DSM-5 delineates two categories of dysfunction for an ASD diagnosis: deficits in 1) Social communication and 2) Behavior; firmly characterizing atypical social communication patterns that affect and disrupt quality interpersonal relationships and daily functioning. Most importantly, DSM-5 stipulates that qualification for ASD requires that the individual present with these deficits in early childhood, similar to the early presentation seen in high-risk siblings. This disclaimer emphasizes the existence of early patterns of social-communicative behavior that impact the developmental trajectory longitudinally.

High-risk children, similar to their ASD siblings, may display measurable deficits in contingent (joint-attentional) social engagement with their parents, and Mundy and Gomes (1998) said that it is joint engagement that allows language to develop more rapidly because the children are tuned in for learning with a more advanced social partner. This intimate interaction promotes the teaching and facilitation of prosocial communication and language (Bruner, 1981; 1983; Vygotsky, 1978), which is also largely accomplished by parents' use and translations of their child's gesture (Dimitrova et al., 2016; Rowe, Özçalışkan, & Goldin-Meadow, 2008; Talbott, Nelson, & Tager-Flusberg, 2016) and the parents' social-communication skills. Because children at high-risk may provide fewer opportunities to their parents for rich social interaction that promotes language learning, due to decreased joint attention or disengagement, their ability to rapidly build their lexicon may be impacted. Consequently, these early delays and characteristics have been shown to impact long-term outcomes (Ben-Sasson, Amit-Ben, Simhon, & Meyer, 2015).

Wetherby and colleagues (2007) assessed social-communication profiles using the *Communication and Symbolic Behavior Scales* (CSBS; Wetherby & Prizant, 2002). In their study, the authors described the social-communication profile as a constellation of behaviors that facilitate social-interaction, pragmatics of language, and, consequently, continued language learning as the behaviors are founded upon tuning in and sharing. Such behaviors include the use of gestures, joint attention, gaze/point following, and gaze shifting. Additionally, they note that response to name, responsive smiling, verbal and non-verbal requesting, and looking to read faces are important pre-linguistic aspects of social-communication. All of these behaviors help to facilitate not only the sharing and learning of new words, but the pragmatics (e.g., nonverbal behaviors and turn-taking) of language that promote the shift from pre-linguistic to linguistic behavior that is seen as infants interact with increasingly more symbol-infused joint engagement (Adamson, Bakeman, & Deckner, 2004; Adamson et al., 2014).

Parents in the current study reported on multiple domains of their child's development using the *Communication and Symbolic Behavior Scales, Infant-Toddler Checklist* and *Caregiver Questionnaire* (Wetherby & Prizant, 2002). The CSBS is a well-studied and reliable parent-report measure (Wetherby et al., 2004) intended to assess children's (6 to 24 months) developmental abilities. The American Academy of Pediatrics published by Johnson, Myers, and the Council on Children with Developmental Disabilities (2007), purported that the CSBS is a well-validated, language development screener for infants, supporting its inclusion in the current study. Consequently, early social-communication is considered a risk factor for the current CRI given its recognition in the literature.

1.4.5 Gesture

The first few years of life are especially critical to long-term development, in particular communicative development. Towards the end of the first year children are fine-tuning a variety of intentional means of communication such as vocalization, gesture, and eye gaze, which beget the development of social engagement with their caregivers (Harwood et al., 2008). Gesture is believed to provide a pathway for expressing content that young children cannot readily verbalize (Iverson & Goldin-Meadow, 2005; Özçalişkan & Goldin-Meadow, 2010; Rowe et al., 2008). Gesture has an important role in early social-communicative skills; as well, gesture may serve as an index of early symbolic skills and as a cornerstone of linguistic development. For children with language difficulties, gesture can be a useful predictor of whether early communication delay will or will not persist (Thal & Tobias, 1992).

Gesture use can be an indicator of language delays and outcomes, in addition to broader developmental outcomes (Gordon & Watson, 2015), and numerous studies have examined gesture to understand its foundation in language (Manwaring, Stevens, Mowdood, & Lackey, 2018). Özçalışkan, Adamson, and Dimitrova (2016) found that in 18-month-old typically developing children and 30-month-old children with ASD, it was deictic gestures, not others, that predicted later language skills. Deictic gestures, including pointing and showing, are the earliest form of gesture that infants produce, eventually they go on to produce more advanced gestures like iconic (pretending to brush hair with a hair brush) and conventional (culturally proscribed items like waving goodbye) gesture. Research has suggested that gesture is notably decreased in children at high-risk (Gordon & Watson, 2015; Iverson et al., 2018; Lebarton & Iverson, 2016; Manwaring et al., 2018) compared to low-risk; similarly, their ASD siblings seemingly produce less gesture overall and utilize fewer types (i.e., deictic and conventional) of gesture. Early on gesture helps children convey that which they cannot readily express (Rowe et al., 2008); gesture then supports them as they move into more symbol-infused communication (2 to 3 word combinations; Özçalışkan & Goldin-Meadow, 2009), and as individuals become more advanced gesture can further supplement spoken language. Dimitrova, Özçalışkan, and Adamson (2016) stated that parents' translations of gesture additionally support spoken language acquisition. Parents' translation fortifies meaning, and the repetition and reinforcement promotes mapping and cements understanding. For children at high-risk, this early lag in gesture, which is foundational for early language and social-interaction (which may both be impaired for children at high-risk), implies that they are at increased risk for unfavorable language outcomes.

The *MacArthur Communicative Development Inventory* (CDI; Fenson et al., 2007) is a frequently used parent-report measure that provides an inventory of child (eight to 42 months) communicative behavior (comprehension and production). Ellawadi and Ellis Weismer (2015) used the CDI to examine parent-reported gesture inventory. Infant gesture is a prelinguistic and engagement—within dyadic interaction—measure known to be predictive of later language. A vast amount of research has established gesture as consequential for and predictive of language development (Iverson & Goldin-Meadow, 2005; Rowe et al., 2008; Veness, Prior, Eadie, Bavin, & Reilly, 2014) and continues to examine gesture repertoire in children with ASD (Dimitrova et al., 2017; Özçalışkan et al., 2016, 2017, and 2018) and high-risk siblings (Gordon & Watson, 2015; Lebarton & Iverson, 2016; Winder, Wozniak, Parladé, & Iverson, 2013).

Winder and colleagues (2013) indicated that along with the CSBS DP, the CDI is often used to assess gesture in infants at high-risk. Paul et al. (2017) also cited the CDI and CSBS as top measures for examining early communication in parent-report and observational formats. Fenson et al., (2007) state that the CDI is especially useful for assessing communicative and symbolic skills in infants who have little experience with language or demonstrate signs of language delay or impairment, similar to a number of children at high-risk. So, gesture reported from the CDI is used as a measure of gesture for the current study, and considered a risk factor for the current CRI given its utility notated in the literature.

1.4.6 Maternal Depressive Symptoms

Research has recognized that mothers are the most consistent social partner in early development. Mothers are integral to language development, and this sentiment is echoed by Tomasello and Farrar (1986) who posited that joint engagement between mothers and their children facilitates lexical development. They stipulated that children must be attentive and motived during social interactions because this best allows them to receive input and retrieve meaning from mother’s language and, thus, further develop more advanced language (Tomasello & Farrar, 1986). Vygotsky (1978) emphasized the importance of intentionality and patience in responsivity and engagement, which has been extended in contemporary literature regarding maternal behavior and developmental outcomes (DiCarlo, Onwujuba, & Baumgartner, 2014; McDuffie & Yoder, 2010; Siller & Sigman, 2008). Depression inherently disrupts functioning due to its dysregulation of mood and psychosomatic sequelae (DSM-5); thus, it is conceivable that mothers who report greater depressive symptoms, or those diagnosed with depression, may have fewer, shorter and less positive instances of sharing interaction with their children, who rely on this engagement to learn language. Kurstjens and Wolke (2001) specifically noted that children of depressed mothers are at-risk due to the effects of maternal depression that lead to decreases in interactions where they may be more responsive, sensitive, and nurturing, thus promoting language.

As children grow older, they rely less on learning from their mothers and more on their foundational skills to continue to extract language and meaning from their environment. Early development is a particularly sensitive period. When children have markedly reduced prosocial interactions with their mothers, where mothers are speaking more and contingently so with their children, this presents children with less exposure to a rich and diverse language environment. In their seminal book and study, Hart and Risley (1995) stressed the importance of parental responsiveness and linguistic diversity to counter potential poverty of language stimulus, as it has a cascading effect on early language exposure, and eventually use, that only grows as children age.

McDuffie and Yoder (2010) conducted a study to probe the types of parental responsivity that predict language in ASD. They found that parent follow-in comments and directives predicted spoken vocabulary, and the number of parent utterances following child focus ($M_{chronologicalage}$ = 40.65 months) and responding to child verbal communication uniquely predicted change in spoken vocabulary. They specifically noted that parent follow-ins may augment information in order for the child with ASD to extract relevant information and rely less on joint attention to learn words. Children do become less dependent on caregivers as language develops, but children at high-risk, in addition to their ASD siblings, may continue to benefit from contingent responsivity because of delays. Depression can challenge the extent to which mothers may reliably go above and beyond to consistently provide the intensive input the child may need.

Many mothers of children with ASD (and children at high-risk) report greater demands and dissatisfaction with service provision (Benevides et al., 2019). Additionally, they report significantly higher levels of parenting stress and are more likely to be diagnosed with depression, and have poorer health outcomes, compared to mothers of typically developing children or those with other developmental disabilities (Cohrs & Leslie, 2017; Hayes & Watson, 2013; Ingersoll & Hambrick, 2011). Depressed mothers or those experiencing greater caregiver burden have been shown to employ lower levels of responsivity and talk less to their children overall (Talbott et al., 2016), which can then impact the child's linguistic environmental exposure. Children are more likely to experience gains from intervention if providers can get buy-in from parents who provide care and embed intervention protocols (e.g., targeting language by increasing contingent, parent follow-ins to child's focus of interest) into daily routines. Compliance is more likely for mothers who are not experiencing poor mental health and will likely be more motivated (which depression affects) to employ change.

The *Center for Epidemiologic Studies Depression Scale-Revised* (CESD-R; Eaton, Muntaner, Smith, Tien, & Ybarra, 2004) is a screening measure of depression and depressive disorder that has been consistently updated since its inception in 1977 to reflect norming studies and changes in the DSM-V; it is also freely accessible. According to APA, it shows high internal consistency, good sensitivity and specificity, shows sensitivity between caregivers and non-caregivers, and is appropriate across racial and ethnic groups (Van Dam & Earleywine, 2011); moreover, it is one of the most utilized in psychiatric epidemiology and public health (CESD-R). Therefore, maternal depressive symptoms is appropriate for inclusion as a risk factor as maternal profile and caregiving experiences in relation to child characteristics factor into child development, and the CESD-R is widely used and validated in the literature (Eaton et al., 2004).

1.4.7 Maternal Concerns for ASD

Parents are a central piece of the puzzle in early child development. They serve as primary caregivers, social partners, interventionists, and reporters of their child's earliest patterns of development (Ben-Sasson et al., 2015). The oldest type of parent report is the diary, which has a long and respected history in developmental psycholinguistics (Fenson et al., 2007). The child's day-to-day progress in early stages is observed and contributes to evaluation; Sacrey et al. (2018a) found that parent-reported observation of behavior via the *Autism Parent Screen for Infants (*APSI; Sacrey et al., 2018a*)* distinguished children diagnosed with ASD at 36 months better than the provider-reported *Autism Observation Scale for Infants* (AOSI, Bryson et al., 2008). A significant concern from parents is their high-risk (similar for parents of children with ASD) children′s social-communication and language. Because ASD is characteristically a disorder with notable social-communicative challenges that begin in early childhood, parents who have concerns for ASD usually detail early concerns in delays in language milestones (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008) and attention and engagement (Cervantes, Matson, & Peters, 2017), and later language usage (e.g., prosody and tone and echolalia; Tager-Flusberg et al., 2005) and comprehension (Dawson, Osterling, Meltzoff, & Kuhl, 2000). Some specific examples of concerns for ASD taken from diaries of the mothers in the current study include, "I am worried that my child may acquire language at a slower pace" and "My child does not initiate joint attention."

Cross-validated studies over the past 10 years (Ben-Sasson, Robins, & Yom-Tov, 2018) and the American Academy of Pediatrics (AAP, 2006; Johnson et al., 2007) have consistently supported that parental concerns at 12 months are predictive of eventual ASD diagnosis (Sacrey et al., 2015; 2018b), usually around 36 months. The predictive validity in parent-reported concerns and ASD diagnoses further extends to clinician agreement and standardized measures around parent ASD screening (Autism Parent Screen for Infants; APSI, Sacrey et al., 2018a). That is, when using standardized measures (e.g., APSI) to assess parent concerns—which may yield a categorical composite by grouping children by level of risk (low to high risk) based on final scores–or obtaining clinical reports, parent concern for ASD (largely centered upon communication concerns) continues to be predictive of (and in agreement with clinicians) child diagnoses. Lo, Klopper, Barnes, & Williams (2017) conducted a large review of medical records of children (N = 677) presenting delays who were referred (M_{age} = 39 months) for evaluation. Of those children, 234 were referred for formal evaluation due to concerns, starting largely from parents, for ASD. Nearly 30% received non-ASD diagnoses (i.e., language delay or congenital disorders), suggesting that concerns are not always predictive of ASD diagnosis. Nevertheless, parents should be actively involved in the process of screening, diagnosis, and monitoring because their concerns underscore and drive their behavior, and they are stakeholders in this process.

Glascoe et al. (2007) stated that service providers should seriously consider parent concerns as early as they are stated to allow these children to be closely monitored in the first years of life. Ben-Sasson et al. (2018) highlighted this point by stating that nearly six months elapse before parents share their concerns with a professional and up to 30+ months before formal diagnoses are made. Altogether, this illuminates the critical importance of parents′ value to the intervention process–they drive the change sought in services–and most importantly they are directly impacted when their child′s needs are or are not met so they must be heard if we intend to provide family-centered care (i.e., mental health). As a result, this study included parent concerns at 12 months to contribute to the examination of parental concerns on later ASD diagnosis and language outcomes. This time point was chosen as it signals a shift in the intentionality and clarity of children′s communication, and numerous studies have also examined indicators at 12 months to predict ASD outcomes at 36 months (Bryson et al., 2008; Sacrey et al., 2015; 2018b).

How parents behave (Ainsworth, 1979; Perryman et al., 2013; Tamis-LeMonda, Kuchirko, & Song, 2014; Topping, Dekhinet, & Zeedyk, 2013)–the extant responsivity literature–is valuable, but their feelings (mental health) and concerns underscore their behavior. Consequently, this study focused on two well-established contributing factors of maternal behavior, concerns (Ozonoff et al., 2009, 2010) and depressive symptoms (Ben-Sasson, Soto, Martínez-Pedraza, & Carter, 2013; Farmer et al., 2012; Hayes & Watson, 2013), and if these risk factors can be entered into a CRI to predict child language outcomes.

In the current study, mothers created weekly diaries over the course of the study (between 6 to 18 months). These self-reported diaries (that mothers were instructed to write weekly) provided a glimpse into some explicit concerns that the mothers had about their child's development, which was previously established as a reliable predictor of outcomes. Therefore, maternal concern is considered a risk factor for the current CRI given its previous examination as a predictor of outcomes.

1.5 Current Study

The purpose of this study was to analyze secondary data collected from a sample of 173 mother-infant dyads comprised of infants at low- and high-risk (those with an elder sibling who has ASD). More specifically, to assess the predictive capacity of a cumulative risk index (CRI) of multiple child and maternal factors. Risk is defined by scores on eight factors: 1) infant sex, 2) receptive language, 3) expressive language, 4) ASD symptomology, 5) social-communication, 6) gesture, 7) maternal depressive symptoms, and 8) maternal concerns for ASD, and their singular and cumulative predictive impact on later receptive and expressive language scores on the MSEL. Cut-offs or dichotomous scores of low- or high-risk will be assessed for every participant on each factor. These factors were all measured at 12 months and are presently established to have implications in language development. Regression will be used to examine the predictive capacity of the CRI and individual risk variables on language development.

All of these widely used assessments and factors established from the literature (Jones, Gilga, Bedford, Charman, & Johnson, 2014) have yet to be concurrently examined to determine the strength of their predictive capacity in a mixed sample (high- and low-risk) of infants, while also considering facets of maternal profile. Hooper and colleagues (1998) stressed the need for research utilizing cumulative risk models in child cognitive development. Burchinal et al. (2000) followed up using a similar model to longitudinally examine numerous social and cognitive risk factors in predicting language and cognitive delays. Researchers have yet to truly undertake this task despite the potential to contribute meaningful research to inform intervention in early child cognitive and language development; especially, to better serve children with developmental disabilities or at heightened risk for ASD and their families. A valid cumulative risk index would allow us to more reliably recognize and flag individuals who, based on a constellation of maternal and child factors, showcase higher index scores. Moreover, the use of these frequently used standardized assessments *and* subject-level indicators may further inform theoretical understanding of predictive factors of language outcomes (standardized). Luyster, Seery, Talbott, and Tager-Flusberg (2011) called for research to summarize what we know about the early assessment of language impairment. Similarly, research taskforces (Filipek et al., 1999; Lord et al. 2005; Tager-Flusberg et al., 2009) and researchers behind the CDI (Fenson et al., 2007) also suggested the need for a stronger methodological approach and systematized understanding of the best practices for studying early developmental problems and affecting the developmental trajectory of comprehensive child development in ASD, namely language.

As a result, this study intends to examine numerous factors that have been widely cited to contribute to and measure language development to assess which of these factors are predictive of language outcomes at 36 months of age. Given the exploratory aspect of this study, hypotheses are largely informed from findings within the extant literature assessing the predictors separately. Consequentially, the research questions for the current study include:

1) At 12 months, do children with siblings with ASD have higher cumulative risk scores than children without siblings with ASD?

For this question, it was hypothesized that infants at high-risk and children later diagnosed with ASD would have larger CRIs than infants at low-risk. These hypotheses are grounded in research literature where it has been heavily noted that children at high-risk also display the broad autism phenotype (Hudry et al, 2014; Jones et al., 2014; Ozonoff et al., 2014); that is, these children display subthreshold levels of difficulties with linguistic, social-communicative (e.g., joint attention/engagement), and gestural behaviors (e.g., deictic). Given their established early signs of atypical behavior, they have been shown to have poorer performances on standardized measures like the MSEL and AOSI (Sacrey et al., 2018a; Zwaigenbaum et al., 2005).

The literature has recognized that children at high-risk display early patterns of development (the broad autism phenotype) similar to the deficits seen in children with ASD, affecting typical patterns of development (Gammer et al., 2015); thus, it was anticipated that low-risk would outperform high-risk on all measures (i.e., CSBS, AOSI, MSEL, and concerns) which would yield higher associations with language outcomes. Early gesture predicts language development:

A considerable amount of research assessing ASD and high-risk with typically developing children has found significant differences in early gesture production and expressive and receptive language, extending across domains of child development in children with ASD and high-risk (Bottema-Beutel, 2016; Chawarska et al., 2014; Franchini et al., 2018; Jones et al., 2014). Therefore, it was predicted that low-risk would outperform high-risk on the gesture measure (CDI). Moreover, mothers of children with ASD—including children at high-risk not diagnosed with ASD—report greater stress, depression, and early concerns (Baker-Ericzn, Brookman-Frazee, & Stahmer, 2005; Benevides et al., 2019; Zuckerman, Lindly, & Sinche, 2015); it was posited that this will furthermore contribute to CRI differences with children at low-risk.

2) Is cumulative risk at 12 months predictive of language at 36 months? What is the predictive power of the CRI model compared to the individual risk variables (risk-factors) model? Does group assignment moderate the predictive capacity of the CRI and/or individual risk variables model on later language outcomes when children are 36 months?

It was hypothesized that the regression models with the CRI as well as the individual risk variables, considered separately, would predict later language outcomes. To compare the predictiveness of the two models, it was hypothesized that the CRI would yield a comparable model of prediction for cumulative risk on language scores similar to the individual risk variables. This hypothesis was inspired by the work done by Burchinal et al. (2000) that found that while the individual risk variables better predicted concurrent outcomes, the CRI was better suited for prospectively predicting developmental patterns, or in this study possibly language outcomes.

Numerous studies have found that early performance on reliable standardized (e.g., AOSI- Zwaigenbaum et al., 2005; MSEL- Landa & Garrett-Mayer, 2006) and parent-report (e.g., CDI- Mitchell et al., 2006; CSBS- Landa et al., 2007) measures of child communication—while controlling for or examining confounds—sometimes predict diagnoses or flag developmental issues. Moreover, infants at high-risk, who have also been identified as displaying the broad autism phenotype, have lower performance on early measures of development due to their similarities to ASD in developmental delays, while also being at –heightened risk for developing ASD. From this, it was hypothesized that group assignment would moderate the predictiveness of the CRI and individual risk variables models on language outcome scores. That is, the magnitude of the relationship between the CRI and the individual risk variables on language outcomes will be dependent upon whether the infant is considered low- or high-risk. Burchinal and colleagues (2000; Hooper et al., 1998) examined factors of social (e.g., education or race), cognitive (e.g., MSEL scores), and subject-level (e.g., sex or risk group assignment) risks, noting correlations between CRIs, factor variables and developmental outcome measures. Thus, it was anticipated that a number of the variables in this study would also be correlated.

3) Does risk at 12 months predict the likelihood of receiving an ASD diagnosis at 36 months?

There is a larger extant literature and public policy detailing the guidelines of screening for ASD (AAP, 2006), but this CRI was originally constructed to add to this and examine predictive means for screening for language delay. The intention of surveying likelihood of an ASD diagnosis in this study, was to see if assessing risk could also provide an accurate means to probe likelihood of ASD diagnosis, despite the small sample of infants diagnosed with ASD (*N* =

36). Therefore, this is an exploratory question undertaken to examine the likelihood of receiving a diagnosis of ASD by 36 months in this study.

2 METHOD

2.1 Study Design

The current study included a subset (*n* = 173) of the 220 mother-child dyads (101 high-risk and 72 low-risk) from the original study. This subset was chosen because these dyads had mostly complete data (at 36 months), which was needed for the present study analyses. The dyads participated in a longitudinal study of infants at high-risk and typically developing children investigated jointly by researchers at Boston University and Boston Children's Hospital/Harvard Medical School. The data were collected as part of a federally-funded NIH grant (PIs Helen Tager-Flusberg and Charles A. Nelson, respectively) in which the investigators tested the efficacy of home-based data collection. Families participated in a phone interview to learn about study criteria and to gather interest. Infants were then screened for exclusion criteria (extended neonatal intensive care unit stays, maternal drug or alcohol use during pregnancy, prematurity, family history of genetic disorders associated with autism spectrum disorder (ASD), and primary languages other than English). The participants were recruited from service providers (i.e., pediatricians, speech-language pathologists, and clinics), web ads, Craigslist, Early Intervention Programs, and print (e.g., Newsweek ads), the Interactive Autism Network, and tested at Boston University Medical Center. Based on their eligibility, potential participants were sent an IRB-approved letter describing the study and included contact information. The families were then able to decide on their participation, and ensured that their participation was voluntary. The researchers attempted to recruit equal numbers of infants at high- and low-risk and their mothers.

Infants were assigned to the high-risk group if they had an elder sibling with ASD (proband), which was assessed by a score of at least 15 on the commonly utilized Social Communication Questionnaire (SCQ; Rutter et al., 2003), diagnosis via the gold-standard Autism Diagnostic Observation Schedule-Revised (ADOS; Lord et al., 2000), or diagnosis by a well-qualified clinician in consideration of assessment scores and developmental history. Infants were assigned to the low-risk group if they had a typically developing elder sibling, assessed using the SCQ, and no first degree relatives with ASD. At the end of the study (when the children were 36 months), all of the participants were assessed using the ADOS—in addition to clinical judgment—to determine ASD diagnosis. All background information regarding the expanded dataset comes from Talbott and colleagues (2015a; 2015b).

The data presented for the current study were taken from two time points (12 and 36 months of age). Infant sex, receptive language, expressive language, ASD symptomology, social-communication, gesture, maternal depressive symptoms, and maternal concerns for ASD (predictor variables) were coded or assessed from archival data at 12 months of age. Clinical outcome and MSEL (receptive and expressive scores) at 36 months of age (outcome variable) was the second time point.

2.2 Participants

The 173 infants (93 boys, 80 girls) had a mean chronological age of 12 months (*SD* = 0.63) at the first time point and 36 months (*SD* = 0.77) at the outcome assessment. Thirty-six children were diagnosed with ASD, 31(86%) were in the high-risk group and 5 (14%) were in the low-risk group. Please see Table 2.1 for more specific demographic information about the participants. Dyads were excluded from the present study if they had dropped out before the infant turned 36 months. A chi-square test for goodness-of-fit was performed to determine whether the infants at high-and low-risk were similar demographically. The demographic factors included: a) level of maternal education, X^2 (7, N = 173) = 8.38, p >.5; b) infant race, X^2 (1, N = 173) = 4.54, p >.05; c) infant ethnicity, X^2 (7, N = 173) = 3.64, p >.05, d) maternal ethnicity, X^2 (1, N = 173) = 3.67, p >.05, e) maternal race, X^2 (3, N = 173) = 3.39, p >.05. None of the factors differed between groups.

Table 2.1 Demographics among mothers and infants

	Infants (n)	Infants (%)	Mothers (n)	Mothers (%)
Sex				
Male	93	54		
Female	80	46		
Group Assignment				
high-risk	101	58		
low-risk	72	42		
Ethnicity				
Hispanic/Latino	9	5	5	3
Non-Hispanic/Latino	164	95	168	97
Race				
White	147	85	157	91
Asian	6	3	9	5
Black	4	2	5	3
More than one race	15	9	2	1
N/A	1	1	0	0
Maternal Education				
High school graduate			3	1.7
Some college			11	6.4
Community college/2-year			11	6.4
4-year college			33	19.1
Some graduate school			16	9.2
Master’s degree			74	42.8
Professional degree			19	11.0
Doctoral degree			6	3.5

Note. N = 173. high-risk = high-risk autism; low-risk = low-risk.

2.3 Measures

As part of the larger study (examining 6 to 36 months of age), the toddlers were assessed to obtain a comprehensive evaluation of various domains of development (i.e., communication, visual-spatial intelligence, social and daily living skills). Additionally, mothers completed a battery of questionnaires and forms about their mental health, child developmental concerns, child language profile (communication inventory), and their child's developmental history. Moreover, the maternal data that was collected included hand-written maternal diaries of four primary domains of concern for their child's development specifically as they relate to ASD (i.e., language, social-communication, restricted or repetitive behaviors, and general/medical concerns). For the current study, we used four of the child assessments and two of the maternal assessments, which are described in greater detail below. Tager-Flusberg et al., (2009) indicated that outcomes from the CDI align with results from other highly rated measures like the CSBS and MSEL suggesting that they are valid measures of developmental skills (Ellawadi & Ellis Weismer, 2015).

2.3.1 Child Measures

Infant sex (male or female) is a subject-level predictor included to assess the degree of predictability on language development at 36 months in boys and girls. Group assignment (low- or high-risk) was provided from the archival data and remained consistent throughout the study (6 to 36 months), until children received final diagnoses of ASD or non-ASD at 36 months of age. Children eventually diagnosed with ASD came from both high-risk (n = 31) and low-risk (n = 5) groups.

2.3.1.1 Assessment measures

The *Mullen Scales of Early Learning* (Mullen, 1995) shows strong construct, concurrent (Farmer, Golden, & Thurm, 2015), and criterion validity (Mullen, 1995) with a number of other reputable developmental measures (Bishop, Guthrie, Coffing, & Lord, 2011), including the Bayley Scales of Infant Development (BSID-II; Bayley, 1993), Differential Abilities Scales (DAS; Elliott, 2007), and the Preschool Language Scale (PLS-5; Zimmerman, Steiner, & Pond, 2011). The correlations with the Bayley Psychomotor Development Index—the motor subscale of the BSID-II—were extremely varied between subscales – Gross Motor (.76) to .28 (Visual Reception). The language scales correlated strongly with other language tests; .85 (Receptive), .72 (Expressive) for Auditory Comprehension and .72 (Receptive), .80 (Expressive) for Verbal Ability (Statistics Solutions, 2018). Children receive raw scores in each domain, these scores can be converted to T scores (range = 20-80), a standardized value that allows comparison or interpretation across domains and accounts for the differences in number of questions and scale of measurement across the domains. As well, developmental quotients can be calculated by summing scores from the verbal (VDQ: receptive and expressive language) and nonverbal (NVDQ: fine and gross motor) measures, and an early learning composite (ELC) summing all scores can provide a composite score of child developmental level.

For the current study, children's receptive and expressive language T scores were used as a measure of language outcomes, and children's fine and gross motor skills T scores were used to control for any differences in the level of development. T scores were used as stated by Mullen (1995) for any interpretation of performance across domains given the differences in number of questions and scale of measurement across the five domains.

The infants were also administered the *Autism Observation Scale for Infants* (Bryson et al., 2000). The AOSI is an 18-item assessment measuring a range of autism-related behaviors (e.g., orienting to name, imitation, attending); it captures a semi-structured interaction between the examiner and child (who often sits on the parent's lap). Infants receive scores from 0 to 2 on eye contact, atypical motor, and sensory behavior, with 0 denoting typicality and 2 atypicality; they receive scores from 0 to 3 on the rest of the domains, similarly with increased rating signifying greater atypicality. The maximum (or summary) score across the 18 items is 50 (from behavior ratings), and total markers are between 0 to 18 (number out of the 18 items reporting atypicality). Bryson and colleagues (2008) reported that the AOSI showed excellent inter-rater reliability at 12 months of age (*ICC* = .93). The test-retest reliability at 12 months was acceptable (*ICC* = .61). The investigators also noted skewed results from low frequencies of non-zero scores on some items, they challenge strong interpretation of these results by citing the complexity of screening tools in examining behavioral indicators that have varying sensitivity and specificity to the disorder itself. Still, they reported that in their study sample, the AOSI produced reliable predictive power of ASD diagnosis at 3 years of age. For the current study, AOSI summary scores were used to gauge autism symptomology.

The *Communication and Symbolic Behavior Scales* (Wetherby & Prizant, 2002) includes a one-page Checklist indexes seven domains of development: 1) emotion and eye gaze; 2) communication; (3) gestures; 4) sounds; 5) words; 6) understanding; 7) object use, and yields three composite scores of communication (numbers 1-3), expressive speech (numbers 4 and 5), and symbolic behavior (numbers 6 and 7). The Checklist combined with the four-page Questionnaire and a Behavior Sample (observed by an examiner between parent and child) comprise a Developmental Profile (CSBS DP; Wetherby & Prizant, 2001). For the current study, raw scores from the Caregiver Questionnaire (range = 0 to 139) when infants were 12 months were used.

The *MacArthur Communicative Development Inventory* (Fenson et al., 2007) is comprised of two major parts, Words and Gestures and Words and Sentences. According to Hudry et al. (2014), “child understands” and “child understands and says” are the two columns of indication that parents endorse thus, yielding raw receptive and expressive language counts. The raw counts are then totaled to generate a communicative inventory; higher scores equate to better performance (Haapsamo et al., 2009). It should be noted that studies have found similarities (correlations) between results on the CDI and the CSBS; both are well-validated measures of early social-communication in childhood that reliably screen for developmental delays. The CDI is strictly parent-report, while the CSBS combines parent-report and clinical observation. Wetherby, Allen, Cleary, Kublin, and Goldstein (2002) examined the reliability and validity of the CSBS and noted that there is scant research using parent report to measure nonverbal communication compared to verbal communication, only the CDI and the CSBS have been used for extensive examination. The current study used scores from the Words and Gestures (for infants 8 to 18 months) subscale as an index of infant gestural communication. There were five total domains of gestures examined, early and late gestures, and up to 63 different gestures (between early and late). According to Fenson et al. (2007) total gestures is the most appropriate score to use for examining gesture; therefore, children could score between 0 (no gesture inventory) to 63 (parent reports complete production of the gesture inventory).

The *Autism Diagnostic Observation Schedule* (ADOS; Lord et al., 2000) is considered the gold-standard measure used to diagnose ASD in individuals (12 months to adulthood). The ADOS measures child social communication, language, and restricted and repetitive behaviors (measures of ASD symptomology as concurrent with diagnostic criteria from the DSM-IV-R, American Psychiatric Association, 1994) using a semi-structured interaction format between the examiner and child. The original study examined infants' ASD symptoms at 18, 24, and 36 months of age. The current study will use the diagnostic results from the ADOS (in addition to clinical judgment) at 36 months of age to determine child ASD status (whether or not the child is high-risk or ASD). Thirty-six children from the current study pool received an ASD diagnosis and 137 received typically developing final diagnoses.

2.3.2 Parent Measures

2.3.2.1 Assessment Measures

The *Center for Epidemiologic Studies Depression Scale-Revised* (Eaton et al., 2004) is a 20-item, self-report screening test for depression and depressive disorder, which measures symptoms defined by the DSM-5. It is widely used in the domain of psychiatric epidemiology (American Psychological Association, n.d.). Answers may be collected in a number of ways (e.g., clinical setting, via telephone, online) and it is available for use in the public domain. It possesses strong internal consistency (Cronbach's αs = .85 – .90) and moderate test-retest reliability (.45 - .70) (Boston Roybal Center for Active Lifestyle Interventions, n.d.). Participants rate each item from 0 ('not at all or 'less than one day') to 3 ('5-7 days' or 'nearly every day for two weeks'), and scores range from 0 to 60, with 60 specifying endorsement of the highest rating for each question. Raw scores equal to or above 16 indicate persons at risk for clinical depression. It was used in the current study to examine current self-reported maternal depressive symptoms not as a diagnostic measure—when the infants were 12 months of age.

Observation (coding): Maternal Concerns. In the diaries created by the mothers with their concerns, Talbott et al. (2015b) created four subscales of these concerns to classify these concerns accordingly: 1) Language (e.g., "I am worried that my child may acquire language at a slower pace."); 2) Social Communication (e.g., "My child does not initiate joint attention."), 3) restricted or repetitive behaviors (e.g., "My child likes to play alone and does not want anyone to joint or interrupt."), and 4) General/Medical Concerns (e.g., "I worry about the future."). The authors then created an ASD concerns subscale derived from a composite of the mothers reported language, social communication, and restricted or repetitive behaviors concerns, all hallmark criteria for ASD, by summing the concerns into one composite. Some mothers turned in multiple diaries during the allotted time point at 12 months (range = 11 to 13 months), so the investigators computed the mean number of ASD-related concerns that mothers reported during this time. In the current study, a dichotomized version was used to examine whether mothers did or did not report early concerns for the development of ASD in their infants.

2.3.3 Study Variables

This study will assess the predictive capacity of cumulative risk index (CRI) of infant and maternal factors that are presently established to have implications in language development at 12 months in predicting child receptive and expressive language at 36 months while controlling for fine and gross motor skill also at 12 months. Thus, the analyses will include eight predictors of interest (CRI), and two control (non-verbal) variables.

Cumulative Risk Index descriptives. The CRI was used to conceptualize a profile of risk, and is defined by the factors in the study associated with later language outcomes, and includes eight dichotomous scores—one for each factor. Participants were considered to be at-risk (1) or no risk (0) for each factor. For the non-assessment measure, infant sex, participants received a score of one if they were male. For assessed measures, receptive and expressive language (MSEL), ASD symptomology (AOSI), social-communication (CSBS), gesture (CDI), maternal depressive symptoms (CESD-R), and concerns, risk scores were given in relation to established cutoffs unique to each measure: Each participant received a final CRI score based off of the summative number of at-risks (1) endorsed; that is, participants had the potential to have a final score between 0 (if they are not at risk across any measures) to 8 (if every at-risk index was endorsed). Burchinal and colleagues (2000; Hooper at al., 1998) and Campana et al. (2015) employed a similar metric to tabulate a final CRI score, and compared this across participants.

Risk Factor (Singular) Cutoffs. Cutoffs for the assessment measures are as follows.

(a) For the receptive and expressive language scored by the MSEL, infants with raw scores more than 1.5 standard deviations below the mean (or scores between 31-35) are considered at risk, per cutoffs in the research literature (Mullen, 1995); therefore; infants with scores 35 or below will be characterized as at risk.

(b) For ASD symptomology scored by the AOSI, infants with seven or more markers (out of 18) or with summary scores of 9 and above considered at risk, per suggestions on the AOSI (Bryson et al., 2000).

(c) For communicative development scored by the CSBS, infants with standard scores less than 6 or percentile scores less than 10 are considered at risk, per suggestions on the CSBS (Wetherby & Prizant, 2001).

(d) For gesture inventory scored by the CDI, infants with raw scores 13 or less are considered at risk, per suggestions on the CDI. The mean number of gestures reported from the norming studies was 27.8 (*SD* = 9.9) and the reported 1.5 standard deviations is 13.

(e) For maternal depressive symptoms scored by the CESD-R, infants with mothers with raw scores at 16 of above are considered at risk, per suggestions on the CESD-R (Eaton et al., 2004).

(f) For maternal concerns, infants with mothers who have concerns are considered at risk, per literature on the validity of parent report (Herlihy et al., 2015; Sacrey et al., 2018b).

Coding of Variables for Analysis. The predictors were analyzed in a regression model to assess the predictive capacity of the factors on language at 36 months. Infant sex and maternal concerns for ASD were dichotomized with males coded as 1 and females coded as 0, endorsing concerns coded as 1 and no concerns endorsed coded as 0 (similar to Veness et al., 2012, measurement of parental concerns). Receptive and expressive language and fine and gross motor, ASD symptomology, social-communication, gesture, and maternal depressive symptoms were originally continuous variables that were dichotomized for the CRI, and include: 1) MSEL-receptive, expressive, fine and gross motor T scores; 2) AOSI- total raw (summary) score; 3); CSBS- total raw score; 4) CDI- total raw score from all components of gesture; and 5) CESD-R- total raw score. Group assignment, the moderator variable, to examine the moderated effect of the relation between risk and language development outcome, was also dichotomized with a 1 for high-risk and low-risk coded as a 0.

2.4 Missing Data

Missing data and attrition are prevalent in longitudinal studies (Widaman, 2006). Notably, there has been much focus on the types of missing data (i.e., missing completely at random, missing at random, or non-ignorable missingness, Widaman, 2006) and how to navigate this when analyzing results to preserve the nature of validity. Because of the longitudinal nature of this work many participants were missing at least one value across the eight scores (the eight predictors and three outcome) they received. To test how the data were missing, Little's missing completely at random test (Little, 1988) was run; the data were considered missing completely at random, X^2 (134, N = 173) = 143.68, p = .268. So as not to bias or decrease generalizability of the results, multiple imputation was used to best fit the model in the face of 13% of missing data (10% or less is considered normal, Evans et al., 2013). Multiple imputation is a process whereby imputations or simulations are created to fit models. In this research, five imputations were generated; values are averaged together to take into account the variance of the missing variables. This produced one set of imputed or pooled values that are actually aggregates of multiple imputed values. The resulting value then replaced the missing value and was used in the subsequent analyses. Only infant sex and group assignment had no missing data. Please see the Appendix for more details on missing data.

2.5 Data Analysis

Before beginning any statistical analyses, a power analysis was conducted using the program *G*Power* (Faul, Erdfelder, Buchner, & Lang, 1996) to determine whether the research design had enough power to detect an effect. The power analysis yielded that at $\alpha = .05$, the sample size required to detect a medium-sized effect ($f^2 = 0.25$; Cohen, 1977) was 109, with an actual power of 0.80, critical $F(8, 100) = 2.03$. All assumptions for parametric testing were met, including multicollinearity and auto-correlation. Normality of the data was assessed by inspecting scatterplots, histograms, and skew/kurtosis; additionally, homoscedascity of the variances was ensured. Parametric tests were used for all analyses as no obvious violations of assumptions including normality were noted. Descriptives for the CRI, in addition to raw scores, SDs, standard scores (where applicable), and mean ranges are reported in Table 3.1. Because gesture was not zero-inflated at 12 months these scores were used. Additionally, the two risk approaches examined are: 1) CRI, which refers to the cumulative risk index (singular score from dichotomized risk) and 2) individual risk variables, which refers to the additive model of scores from the risk factors.

1) At 12 months, do children with siblings with ASD (high-risk group) have higher risk scores than children without siblings with ASD (low-risk group)?

First, the degrees of correlation amongst the predictor variables were examined, see Table 3.2. Then, according to the metric listed above for determining risk, participants received a singular summative risk factor score or CRI. Descriptives like the frequency of CRIs of 0-8 (i.e., how many children had CRIs of 0, 1, 2, etc.), mean number of CRIs, the range of CRIs, and descriptives for the individual risk variables themselves were also computed (i.e., frequencies, means, and ranges for each risk factor).

To answer the question, an independent samples *t*-test was conducted to assess any group differences in the above listed CRI scores between the infants at high- and low-risk.

2) Is cumulative risk at 12 months predictive of language at 36 months? What is the predictive power of the CRI model compared to the singular, additive? Does group assignment moderate the predictive capacity of the CRI and/or individual risk variables on later language outcomes when children are 36 months?

To answer this question, four, separate hierarchical regressions were conducted for the CRI and individual risk variables models. Two models for the CRI and two for the individual risk variables were analyzed, one model with receptive and another model with expressive language as the outcome variable. In the first model, the control variables (fine and gross motor scores) were entered into the first block and CRI was entered into the second block, to assess any additional variance contributed to the model by CRI above and beyond the controls. In the second model, the control variables (fine and gross motor scores) were entered into the first block and all of the eight individual risk variables were entered into the second block, again to assess any additional variance contributed to the model by the individual risk variables above and beyond the controls in separate models. Squared semi-partial correlations in the second model were examined to assess the unique contributions of each predictor separate from the others. To examine the predictiveness between both hierarchical regression models, ΔR^2 values for the second step were compared.

Additionally, moderated multiple regression models were conducted to examine the possibility of group assignment moderating the predictiveness of risk on language outcomes. Moderation analyses were run using the PROCESS (Hayes, 2017) macro for SPSS. For the first model, CRI was entered as the independent variable, group assignment as the moderator, fine and gross motor scores as covariates (to control for developmental level), and was separately run for receptive and expressive language outcome variables. The same was done for the individual risk variables, the eight risk variable predictors were entered into separate regression models to examine whether any interactions accounted for additional unique variance to receptive and expressive language outcomes at 36 months.

3) Does risk at 12 months predict the likelihood of receiving an ASD diagnosis at 36 months?

For this research question, two logistic regressions were conducted. The models were underpowered due to the sample size, but they were run with CRI and individual risk variables, separately, entered as independent variables—along with the two control variables—predicting the odds of receiving a diagnosis of ASD (coded 1), the binary outcome variable.

3 RESULTS

Data analyses were conducted to evaluate the cumulative risk index (CRI) for language delay (and autism spectrum disorder [ASD]) as a measure of cumulative risk assessed with numerous factors implicated in or used to measure language development. To determine the appropriate course of analysis, data were examined for outliers, kurtosis, and skewness in SPSS Version 23 statistical package (IBM Corp, 2013). The initial examination of the data confirmed normality of the dataset and the use of parametric analyses. Correlational analyses were conducted to evaluate the relations amongst the eight predictors, two control variables, and additional variables (i.e., moderator and outcome) in the CRI.

3.1 Descriptive Statistics

The means and standard deviations for the measures are presented in Table 3.1 and frequencies pertaining to the CRI are presented in Table 3.5. None of the infants had scores that were significantly below developmental level; that is, none of the infants scored in ranges indicative of severe intellectual and developmental disabilities. Bivariate correlational analyses were conducted to examine the degree of association among all the variables and are reported in tables 3.2, 3.3, and 3.4. Weak to moderate, significant correlations ($p < .01$) were seen amongst a number of the measures, as well as weak, significant correlations ($p < .05$). However, few of the correlations were greater than $r = .50$, only correlations between the *Mullen Scales of Early Learning* (MSEL) expressive language (at 12 months) and *Communication and Symbolic Behavior Scales* (CSBS; $r = .53$), CSBS and *MacArthur-Bates Communicative Development Inventory* (CDI; $r = .75$), and MSEL receptive and expressive scores at 36 months ($r = .68$). This is consistent with previous research indicating that the CSBS and CDI are correlated and valid measures of language development (Ellawadi & Ellis Weismer, 2015; Tager-Flusberg et al., 2009). The outcome language measures, MSEL receptive and expressive were significantly correlated with some of the measures in addition to each other, group assignment, and diagnostic outcome (ps $< .05$). Additionally, separate correlations between low- and high-risk participants were examined to assess any distinct differences in correlations by group, these results are in Tables 3.3 and 3.4. Significant correlations were also seen amongst variables in the children at high- and low-risk separately, but only correlations between infants at high- and low-risk's

CSBS and CDI and MSEL receptive and expressive language at 36 months were greater than *r* = .50.

Table 3.1 Descriptive Statistics for Risk Factor Continuous Scores

	M (SD)	Minimum	Maximum	Median
MSEL_12 receptive	44.38 (8.10)	20	71	44
MSEL_12 expressive	47.12(9.19)	20	78	46
MSEL_12 fine motor	59.26(9.58)	33	80	60
MSEL_12 gross motor	42.54(10.11)	20	67	43
AOSI	3.68(2.67)	0	17	3
CSBS	62.91(15.82)	26	116	62.87
CDI	19.91(8.17)	2	50	19
CESD-R	10.35(8.38)	0	44	9.43
MSEL_36 receptive	55.02(10.03)	20	80	56
MSEL_36 expressive	57.21(9.27)	20	80	58

Note. *N* = 173. MSEL_12 = Mullen Scales of Early Learning measured at 12 months; MSEL_36 = Mullen Scales of Early Learning measured at 36 months; AOSI = Autism Observation Scale for Infants; CSBS = Communication and Symbolic Behavior Scales; CDI = Mac-Arthur Bates Communicative Development Inventories; CESD-R = Center for Epidemiologic Studies Depression-Revised.

Table 3.2 Bivariate Correlations Among Predictors

		2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Sex	-	-.04	.16*	.18*	.20**	.00	.00	.20**	.23**	.06	-.14	.07	.09	-.13
2. GA	-	-	-.04	-.21**	.05	-.17*	-.01	-.27**	-.20**	.10	.08	-.24**	-.30**	.32**
3.Msel_r[a]	-	-	-	.40**	.48**	.23**	-.002	.28**	.32**	.06	-.16*	.19*	.31**	-.25**
4.Msel_e[a]	-	-	-	-	.43**	.15*	-.02	.53**	.36**	-.08	-.22**	.25**	.30**	-.11
5.Msel_f[a]	-	-	-	-	-	.32**	-.09	.29**	.36**	.14	-.01	.19*	.24**	-.12
6.Msel_g[a]	-	-	-	-	-	-	-.07	.31**	.32**	.06	.15	.20**	.21**	.02
7.AOSI	-	-	-	-	-	-	-	-.10	.03	.15*	.37**	.06	-.07	.03

8.CSBS	-	-	-	-	-	-	-	-	.75**	-.05	-.25**	.24**	.35**	-.10
9. CDI	-	-	-	-	-	-	-	-	-	-.11	-.06	.28**	.32**	-.20**
10. CESDR	-	-	-	-	-	-	-	-	-	-	.27**	.00	.01	.11
11. Concern	-	-	-	-	-	-	-	-	-	-	-	.09	.06	.09
12. Msel_r[b]	-	-	-	-	-	-	-	-	-	-	-	-	.68**	-.29**
13. Msel_e[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-.38**
14. Dx	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. GA = Group Assignment; Msel = Mullen Scales of Early Learning: r = receptive, e = expressive, f = fine motor, g = gross motor; AOSI = Autism Observation Scale for Infants; CSBS = Communication and Symbolic Behavior Scales; CDI = Mac-Arthur Bates Communicative Development Inventories; CESDR = Center for Epidemiologic Studies Depression-Revised; Dx = diagnosis. ***p* < .01. **p* < .05.
[a]Mullen Scales of Early Learning measured at 12 months; and measured [b]at 36 months.

Table 3.3 Bivariate Correlations Among Predictors in Low-Risk Infants

		2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Sex	-	.21	.17	.17	.03	-.03	.34**	.22	.14	-.14	.03	.10	-.12	-.12
2.Msel_r[a]	-	-	.30*	.47**	.35**	-.01	.19	.25	.07	-.14	.03	.18	-.28*	-.03
3.Msel_e[a]	-	-	-	.46**	-.05	-.00	.45**	.30**	-.12	-.25	.10	.15	-.03	.00
4.Msel_f[a]	-	-	-	-	.33**	-.13	.24*	.41**	.03	.11	.12	.12	-.22	.02
5.Msel_g[a]	-	-	-	-	-	-.01	.16	.30**	.11	.34**	.06	-.17	-.09	.01
6.AOSI	-	-	-	-	-	-	-.12	.00	.14	.34**	.06	-.17	-.09	.01
7.CSBS	-	-	-	-	-	-	-	.72**	.02	-.20	.16	.21	.07	.05
8. CDI	-	-	-	-	-	-	-	-	-.02	.07	.21	.15	-.12	.00
9. CESDR	-	-	-	-	-	-	-	-	-	.20	.02	-.01	-.04	.05
10. Concern	-	-	-	-	-	-	-	-	-	-	.09	.05	-.16	.09
11. Msel_r[b]	-	-	-	-	-	-	-	-	-	-	-	.60**	-.09	.04
12. Msel_e[b]	-	-	-	-	-	-	-	-	-	-	-	-	-.42**	-.09
13. Dx	-	-	-	-	-	-	-	-	-	-	-	-	-	.17
14. Edu	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. Msel = Mullen Scales of Early Learning: r = receptive, e = expressive, f = fine motor, g = gross motor; AOSI = Autism Observation Scale for Infants; CSBS = Communication and Symbolic Behavior Scales; CDI = Mac-

Arthur Bates Communicative Development Inventories; CESDR = Center for Epidemiologic Studies Depression-Revised; Dx = diagnosis; Edu = Maternal Education. ***p* < .01. **p* < .05. [a]Mullen Scales of Early Learning measured at 12 months; and measured [b]at 36 months.

Table 3.4 Bivariate Correlations Among Predictors in High-Risk Infants

		2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Sex	-	.12	.18	.22*	-.03	.04	.13	.22*	.01	-.14	.08	.08	-.14	-.01
2.Msel_r[a]	-	-	.45**	.50**	.14	.01	.32**	.37**	.05	-.17	.26**	.40**	-.26**	-.04
3.Msel_e[a]	-	-	-	.44**	.23*	-.04	.53**	.35**	-.02	-.18	.26**	.32**	-.06	.02
4.Msel_f[a]	-	-	-	-	.35**	-.05	.35**	.36**	.19	-.10	.26**	.36**	-.12	-.23*
5.Msel_g[a]	-	-	-	-	-	-.14	.34**	.29	.06	.05	.24*	.25*	.12	.09
6.AOSI	-	-	-	-	-	-	-.11	.07	.18	.42**	.06	.01	.11	.13
7.CSBS	-	-	-	-	-	-	-	.77**	-.04	-.26**	.19	.34**	-.03	-.11
8. CDI	-	-	-	-	-	-	-	-	-.14	-.12	.26**	.36**	-.18	.04
9. CESDR	-	-	-	-	-	-	-	-	-	.31**	.03	.07	.13	-.03
10. Concern	-	-	-	-	-	-	-	-	-	-	.12	.10	.15	-.08
11. Msel_r[b]	-	-	-	-	-	-	-	-	-	-	-	.68**	-.27**	-.02
12. Msel_e[b]	-	-	-	-	-	-	-	-	-	-	-	-	-.30**	-.13
13. Dx	-	-	-	-	-	-	-	-	-	-	-	-	-	.15
14. Edu	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. Msel = Mullen Scales of Early Learning: r = receptive, e = expressive, f = fine motor, g = gross motor; AOSI = Autism Observation Scale for Infants; CSBS = Communication and Symbolic Behavior Scales; CDI = Mac-Arthur Bates Communicative Development Inventories; CESDR = Center for Epidemiologic Studies Depression-Revised; Dx = diagnosis; Edu = Maternal Education. ***p* < .01. **p* < .05. [a]Mullen Scales of Early Learning measured at 12 months; and measured [b]at 36 months.

3.2 RQ 1: Cumulative Risk Index

The first research question addressed the summative indices of risk for the infants. To examine the first part of this question, dichotomized indices of risk were aggregated across measures and the participants (range 0 to 7). Frequencies for the CRI are listed in Table 3.5. For the entire sample (N = 173), the mean CRI was 1.67 (SD = 1.36). The mean CRI for low- (n = 72) and high-risk (n = 101) groups were 1.37 (SD = 1.09) and 1.98 (SD = 1.49), respectively. An independent samples *t*-test revealed statistically significant differences with a moderate effect in the CRI between the low- and high-risk groups, $t(170.80) = -2.58$, $p = .011$, $d = .47$; that is, the high-risk group had a larger CRI, overall, than the low-risk group. The frequency counts of the sums for the CRI yielded that the majority of low- (n = 31%) and high-risk (n = 29%) infants had a CRI of 1. Please see Figure 3.1 for further details regarding frequencies of total CRI between children at high- and low-risk.

Table 3.5 Frequencies for Cumulative Risk Index

	Frequency	Percent
Sex		
Male	93	54
Female	80	46
MSEL_12_r		
Low-risk	145	84
High-risk	28	16
MSEL_12_e		
Low-risk	160	92.5
High-risk	13	7.5
AOSI		
Low-risk	163	94
High-risk	10	6
CSBS		
Low-risk	148	85.5
High-risk	25	14.5
CDI		
Low-risk	137	79
High-risk	36	21
CESD		
Low-risk	134	77.5
High-risk	39	22.5
Concerns		
No Concerns	115	66.5
Concerns	58	33.5

Note. N = 173. GA = Group Assignment; HRA = high-risk autism; LRC = low-risk control. MSEL_12 = Mullen Scales of Early Learning measured at 12 months; MSEL_36 = Mullen Scales of Early Learning measured at 36 months; AOSI = Autism Observation Scale for Infants; CSBS = Communication and Symbolic Behavior Scales; CDI = Mac-Arthur Bates Communicative Development Inventories; CESD-R = Center for Epidemiologic Studies Depression-Revised.

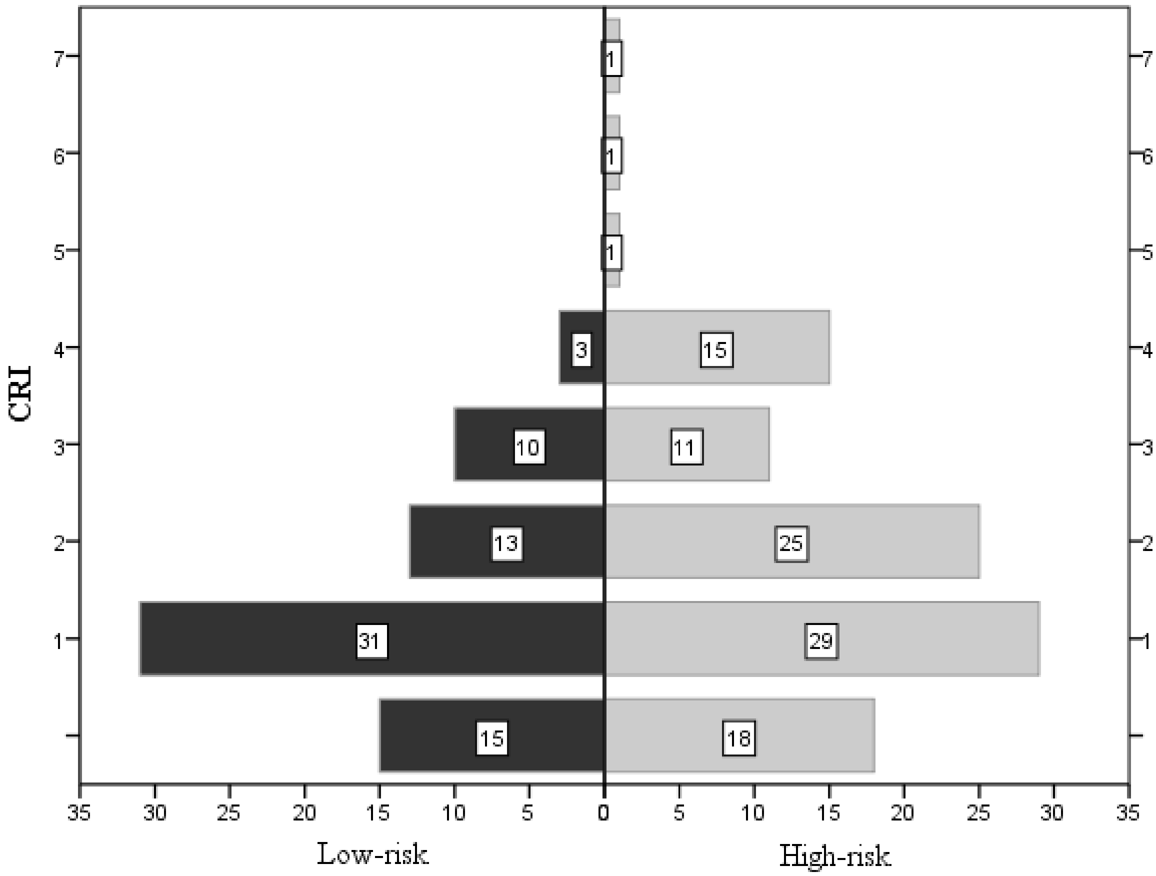

Figure 3.1. Population pyramid for the frequency of sums of CRI between low-risk and high-risk.

3.3 RQ 2a: CRI and Individual Risk Variables Hierarchical Regression Models

The second research question addressed the predictive capacity of the CRI and individual risk variables on receptive and expressive language, separately. This was done using a hierarchical regression model in which the control variables were entered in Step 1 and CRI or the individual risk variables (separate models) were entered in Step 2. Hierarchical regression models permitted examination of the shared and potential unique contributions of the CRI and risk-factors on language outcome scores on the MSEL, over and above nonverbal skills. The overall predictor model including the CRI was statistically significantly for the receptive language, $F(3, 172) = 3.59$, $p = .015$, $R^2 =.06$, and expressive language outcomes, $F(3, 172) = 6.83$, $p < .001$, $R^2 =.11$. The CRI explained an additional 0.2% of the variance in receptive language ($p = .559$), and an additional 3% of the variance in expressive language ($p = .019$). For expressive language scores only, the CRI ($sp^2 = .03$) and fine motor scores ($sp^2 = .03$) uniquely predicted expressive language; such that, for the CRI and fine motor scores, each additional risk an infant had in CRI results in a predicted 1.21 points decrease in expressive language score and 1 T (standardized MSEL) score increase in fine motor scores results in a predicted .16 T score increase in expressive language. This suggests that having a larger CRI at 12 months was associated with lower expressive language scores, and higher fine motor scores were associated with higher expressive language scores. See Table 3.6 for full regression results.

Table 3.6 Hierarchical Regression Analyses for Cumulative Risk Index.

Variable	*B*	SE_B	*Β*	*T*	*P*	ΔR^2	LLCI	ULCI
MSEL_r								
MSEL_12_f	.14	.08	.13	1.63	.105		-.03	.30
MSEL_12_g	.15	.08	.15	1.92	.057		-.00	.31
CRI	-.33	.57	-.05	-.59	.559	.002	-1.45	.79
MSEL_e								
MSEL_12_f	**.16**	**.08**	**.16**	**2.10**	**.038**		**.01**	**.31**
MSEL_12_g	.12	.07	.13	1.68	.095		-.02	.26
CRI	**-1.21**	**.51**	**-.18**	**-2.36**	**.019**	**.034**	**-2.22**	**-.20**

*Note***.** *B* = unstandardized regression coefficient; SE_B = Standard error of the coefficient; *β* = standardized regression coefficient; LLCI = lower level confidence interval; ULCI = Upper level confidence interval; MSEL = *Mullen Scales of Early Learning*; MSEL_12 = scores at 12 months; f = fine motor; g = gross motor; CRI = cumulative risk index.

The hierarchical regression model for the individual risk variables statistically significantly predicted receptive language, $F(10, 172) = 2.48$, $p = .009$, $R^2 =.13$, and expressive language, $F(10, 172) = 4.70$, $p < .001$, $R^2 =.23$. The individual risk variables explained an additional 8% of the variance in receptive language (p = .091), and an additional 15% of the variance in expressive language (p < .001). For expressive language scores only, concerns (sp^2 = .04) and receptive language scores (sp^2 = .04) at 12 months uniquely predicted expressive language; such that, for the concerns and receptive language scores, reporting concerns (versus reporting no concern) results in a predicted 4.45 points increase in expressive language, and 1 T (standardized MSEL) score predicted increase in receptive language scores at 12 months results in .25 T score increase in expressive language. All of this to say that, reporting concerns for ASD at 12 months was associated with higher expressive language scores, and higher receptive language scores at 12 months was associated with higher expressive language scores, all at 36 months. Please see Table 3.7 for further details. Even though the block of individual risk variables explained a statistically significant amount of variance in receptive language overall, none of the unique effects of any of the individual risk variables was statistically significant.

In both the CRI and individual risk variables models, the predictors accounted for greater variance in expressive than receptive language, suggesting slightly higher predictiveness of the models on expressive language scores. To determine whether the CRI or risk-factor was a better fit for examining the predictiveness of cumulative risk on language development, ΔR^2 was compared between both models. For the CRI change in R^2 (ΔR^2), adding in CRI over and above controls added 0.2% additional variance to receptive and 3% additional variance to expressive; for the individual risk variables, ΔR^2 for receptive and expressive language was 8% and 15%, respectively. Consequently, the individual risk variables accounted for more variance for both outcome variables after parsing out controls, and, was thus, the better fit for examining risk.

Table 3.7 Hierarchical Regression Analyses for Individual Risk Variables.

Variable	*B*	SE_B	*Β*	*t*	*p*	sp^2	LLCI	ULCI
MSEL_r								

MSEL_12_f	-.002	.10	-.002	-.02	.985	.00	-.20	.20
MSEL_12_g	.09	.08	.09	1.06	.291	.01	-.08	.25
Sex	.19	1.55	.01	.12	.905	.00	-2.88	3.25
MSEL_12_r	.08	.11	.07	.74	.458	.00	-.14	.30
MSEL_12_e	.18	.11	.17	1.72	.088	.02	-.03	.39
AOSI	.06	.31	.02	.18	.857	.00	-.55	.66
CSBS	.01	.09	.03	.12	.902	.00	-.16	.18
CDI	.20	.15	.16	1.28	.201	.01	-.11	.50
CESD	-.02	.10	-.02	-.20	.841	.00	-.21	.17
Concern	2.90	1.92	-.02	-.20	.841	.01	-.88	6.69
MSEL_e								
MSEL_12_f	-.02	.09	-.02	-.17	.863	.00	-.18	.16
MSEL_12_g	.02	.07	.02	.30	.762	.00	-.12	.17
Sex	.33	1.36	.02	.25	.806	.00	-2.34	3.01
MSEL_12_r	**.25**	**.10**	**.22**	**2.62**	**.010**	**.04**	**.06**	**.44**
MSEL_12_e	.13	.09	.13	1.37	.173	.01	-.06	.31
AOSI	-.43	.27	-.12	-1.60	.113	.01	-1.0	.10
CSBS	.14	.07	.23	1.82	.070	.02	-.01	.28
CDI	.05	.13	.04	.36	.722	.00	-.22	.31
CESD	-.02	.09	-.02	-.24	.814	.00	-.19	.15
Concern	**4.45**	**1.67**	**.23**	**2.66**	**.009**	**.04**	**1.14**	**7.75**

*Note***.** *B* = unstandardized regression coefficient; SE_B = Standard error of the coefficient; *β* = standardized regression coefficient; LLCI = lower level confidence interval; ULCI = Upper level confidence interval; MSEL = *Mullen Scales of Early Learning*; MSEL_12 = scores at 12 months; r = receptive language; e = expressive language; f = fine motor; g = gross motor; AOSI = *Autism Observation Scale for Infants*; CSBS = *Communication and Symbolic Behavior Scales*; CDI = *MacArthur-Bates Communicative Development Inventory*; CESD-R = *Center for Epidemiologic Studies Depression Scale-Revised*.

3.4 RQ 2b: Moderated Regression Models

In addition to the first part of the second question, the degree to which group assignment (low- or high-risk) moderated the predictive relationship between the CRI and risk-factor models on receptive and expressive language was assessed. For the CRI model, expressive and receptive language were entered as outcome variables, nonverbal skills as controls, group assignment as the moderator, and the CRI as the predictor. The risk-factor model was similarly set up, but separate models had to be run for each predictor as PROCESS permits only one predictor (independent variable) to be analyzed at a time. Therefore, covariates included controls and all other variables that were not entered as predictors for that model (e.g., sex as a predictor and all others as covariates and then MSEL receptive at 12 months and all others as covariates). Results for the moderation determined that the controls, CRI and group assignment accounted for 7% of the variance in receptive language outcomes, $F(3, 169) = 3.98$, $p = .009$, and 13% of the variance in expressive language, $F(3, 169) = 2.48$, $p < .001$. In Table 3.8 only interactions in the model were reported, none of the interactions run were significant. Thus, there is no evidence of differences by group for the relation of the CRI or the individual risk variables with language outcomes.

Table 3.8 Moderated Multiple Regression with Group Assignment

Variable	*B*	SE_B	*t*	*p*	ΔR^2	LLCI	ULCI
Receptive Language							
CRI	.29	1.06	.27	.788		-1.81	2.38
CRI X GA	-.96	1.25	-.77	.439	.00	-3.43	1.50
Model 1	1.34	2.97	.45	.653	.00	-4.53	7.21
Model 2	.29	.19	1.56	.121	.01	-.08	.66
Model 3	.17	.17	1.00	.320	.06	-.17	.51
Model 4	.03	.58	.05	.961	.00	-1.12	1.18
Model 5	.03	.11	.27	.785	.00	-.19	.25
Model 6	.16	.19	.82	.414	.00	-.22	.53
Model 7	-.01	.18	-.04	.972	.00	-.37	.35

Model 8	2.06	3.24	.64	.526	.00	-4.33	8.45
Expressive Language							
CRI	-.82	.95	-.86	.391		-2.69	1.06
CRI X GA	-.60	1.12	-.54	.589	.00	-2.81	1.60
Model 1	.77	2.56	.30	.765	.00	-4.28	5.82
Model 2	.22	.16	1.35	.178	.01	-.10	.53
Model 3	.10	.15	.68	.495	.00	-.19	.39
Model 4	.27	.50	.54	.591	.00	-.72	1.26
Model 5	.06	.10	.65	.517	.00	-.13	.25
Model 6	.25	.16	1.53	.128	.01	-.07	.57
Model 7	.06	.16	.37	.715	.00	-.25	.37
Model 8	1.57	2.78	.56	.573	.00	-3.93	7.07

*Note***.** *B* = unstandardized regression coefficient; SE_B = Standard error of the coefficient; *β* = standardized coefficient. Model 1 = sex x GA; Model 2 = *Mullen* receptive language x GA; Model 3 = *Mullen* expressive language x GA; Model 4 = *AOSI* x GA; Model 5 = *CSBS* x GA; Model 6 = *CDI* x GA; Model 7 = *CESD-R* x GA; and Model 8 = Concern x GA. Each interaction was entered separately above main effects.

3.5 RQ 3: Predicting ASD with the CRI and Individual Risk Variables

To examine the predictive capacity of determining ASD diagnosis, while controlling for nonverbal factors, from the CRI and risk-factors, binary logistic regressions were run with ASD diagnosis as the outcome (0 = TD and 1 = ASD). Results from the CRI model yielded 79% accuracy (Nagelkerke R^2 = .10) in determining the likelihood of diagnosis of ASD, and the risk-factor model yielded 84% accuracy (Nagelkerke R^2 = .18) in determining the likelihood of diagnosis of ASD. Controlling for nonverbal factors, for each additional risk for the CRI, the likelihood that the participant will have a diagnosis of ASD increases by 1.48; that is, the odds of being in the ASD group increased by 48.3%, CIs[1.12, 1.96]. For the individual risk variables model, controlling for nonverbal factors and other risk predictors, as receptive language scores at 12 months decrease by 1 T (standardized MSEL) score there is an increased likelihood of .93.

For each decrease in one gesture, there is an increased likelihood of .91. That is, the odds of being in the ASD group increased by 7%, CIs[.87, .98] and 9%, CIs[.83, 1.00]. Please see Table 3.9 for detailed results.

Table 3.9 Likelihood of ASD Diagnosis

Variable	Odds Ratio	*B*	*SE*	*p*	Nagelkerke R^2	LLCI	ULCI
Model 1					.10		
MSEL_12_f	.98	-.03	.02	.237		.94	1.02
MSEL_12_g	1.02	.02	.02	.247		.98	1.07
CRI	1.48	.39	.14	.006		1.12	1.96
Model 2					.18		
MSEL_12_f	1.01	.01	.03	.807		.95	1.06
MSEL_12_g	1.02	.02	.02	.312		.98	1.07
Sex	1.57	.45	.43	.298		.67	3.68
MSEL_12_r	.93	-.08	.03	.013		.87	.98
MSEL_12_e	1.0	-.01	.03	.882		.94	1.06
AOSI	1.04	.04	.09	.679		.88	1.23
CSBS	1.03	.03	.02	.211		.98	1.08
CDI	.91	-.10	.05	.039		.83	1.00
CESD	1.02	.02	.03	.340		.98	1.08
Concern	.93	-.08	.52	.885		.34	2.57

Note. *B* = unstandardized regression coefficient; SE_B = Standard error of the coefficient; β = standardized regression coefficient; LLCI = lower level confidence interval; ULCI = Upper level confidence interval; MSEL = *Mullen Scales of Early Learning*; MSEL_12 = scores at 12 months; r = receptive language; e = expressive language; f = fine motor; g = gross motor; AOSI = *Autism Observation Scale for Infants*; CSBS = *Communication and Symbolic Behavior Scales*; CDI = *MacArthur-Bates Communicative Development Inventory*; CESD-R = *Center for Epidemiologic Studies Depression Scale-Revised*.

4 DISCUSSION

The research aims intended to examine the utility and predictiveness of a cumulative risk index (CRI) of multiple risk factors that are presently established to have implications in language development, in a sample of infants at high- and low-risk for ASD whose receptive and expressive language was assessed at 36 months. Currently, there has been no examination of cumulative risk and its effects on language outcomes in a sample of infants at high- and low-risk, some of whom were eventually diagnosed with ASD. Moreover, this study is unique amongst other studies examining cumulative risk in development in that the predictiveness of the singular CRI was compared to the predictiveness of a multi-risk-factor additive regression model for language. The results from the study indicated that the CRI accounted for a small amount of the expressive language variance, and the CRI uniquely predicted expressive language. Comparatively, the set of individual risk variables accounted for a moderate amount of the receptive and expressive language variance, although the only unique effects of the individual risk variables detected were that receptive language at 12 months and maternal concerns each predicted expressive language. These findings suggest that for examining risk on language outcomes, the CRI accounted for an acceptable amount of variance in predicting expressive language compared to the standard regression models in the extant developmental literature. As well, both the CRI and individual risk variables significantly predicted likelihood of ASD diagnosis at 36 months, and these results seemed to be driven by early receptive language and gesture.

4.1 Cumulative Risk Index

A primary aim of the current study was to longitudinally assess the unique contributions of the CRI measured at 12 months on receptive and expressive language outcomes at 36 months. Numerous child factors and some maternal factors were considered to foster a more comprehensive understanding of the possible contributions of separately well-established indicators and how they converge to predict outcomes. Moreover, the use of empirically established indices of risk (cut-off scores) intended to further parse out information about the predictors. The separate risk indices are rooted in literature that has cultivated models and methodological approaches to study risk given the capacity to recover the developmental trajectory through early detection and intervention. Infants were considered high-risk if they had an elder sibling with ASD. Significant differences were found in the relative size of the CRI between infants at high- and low-risk at 12 months. Infants at high-risk had larger CRIs than infants at low-risk. This is not surprising as such findings in early differences in behavior and social communication have been reported (Herlihy et al., 2015; Ozonoff et al., 2009; Schwichtenberg et al., 2010) that distinguish children at high-risk from low-risk largely due to the developmental characteristics of the broader autism phenotype.

The CRI combined factors in child social-communication and behavior in addition to maternal characteristics to better understand risk. ASD symptomology, characteristics of social-communication known to increase undesirable language outcomes, inherently disrupt early language learning which is largely acquired through social-interaction with parents. Parental concerns for development can provide an index of relative differences regarding children at high-risk's early developmental experience, in addition to their measured developmental profile. Parents of children with ASD (also parents of children at high-risk) are also more likely to report higher depressive symptoms (Benevides et al., 2019). Taken together, siblings of children with ASD, whose parents are also more likely to be concerned about their development (Talbott et al., 2015b), were expected and yielded larger CRIs overall because of the early recognized profile of risk that distinguishes them from children without familial ASD risk.

The extant literature supports clearer and more consistent behavioral patterns at 12 months than earlier periods in predicting later outcomes, like at 36 months (Szatmari et al., 2016), specifically. Early concerns from parents of children at high-risk usually center on social-communicative and language behaviors, including diminished capacity for joint attention (Herlihy et al, 2015), which may be characterized by disinterest in shared activities with a social partner, non-orientation to name, pointing and showing, or limited to no eye contact (Paparella, Goods, Freeman, & Kasari, 2011); these are recognized areas of deficit as well (Ozonoff et al., 2009). As discussed, joint attention is predictive of language development; thus, these concerns for ASD are often communication and language concerns that may be indicative of future language problems (Mundy et al., 2007). Moreover, Schwichtenberg et al. (2010) noted that siblings of children with ASD underperform on developmental measures compared to other children without ASD, because of their phenotypic profile, so it was expected for their scores on the current study measures to be lower overall. Therefore, the resultant significant differences seen in the CRI at 12 months between the infants are plausible because of these measured differences in early and later language supported by empirical literature regarding differences in both child and maternal characteristics. The factors assessed are measurable at this time point and larger high-risk literature has reliably observed differences between the groups when the measures (e.g. Schwichtenberg et al., 2010) were examined separately.

Given that siblings of children with ASD are known to be at increased risk for social-communication and language deficits and higher maternal depressive symptoms and concerns, the findings support the extant literature on early differences in language outcomes between these children and those without elder siblings with ASD. The findings also support one of the original hypotheses positing that siblings of children with ASD were expected to be higher risk, as indexed by the CRI.

4.2 Predictiveness of the CRI and Risk-Factor Analyses

Another primary aim of the current study was to longitudinally assess the unique contributions of the risk-factors on receptive and expressive language outcomes. Additionally, two models for risk, CRI and additive regression, were compared to examine which better predicted cumulative risk on language outcomes. The CRI and the block of individual risk variables each significantly predicted expressive language. This suggests that in the presence of controls, the CRI uniquely predicted expressive language (3% unique variance), as did maternal concerns and infants' early comprehension. It is difficult to assume any one explanation to account for outcomes in receptive and expressive language given broad homogeneity in the language environment and exposure, and the challenges in accurately measuring early comprehension compared to production (Iverson et al., 2018). Upon comparison, the block of individual risk variables better predicted expressive language risk. Both models did evidence that infants who experience greater risk scored lower on the language measure at 36 months.

The research has recognized that there is utility in both CRI and an additive, individual risk approach (Evans et al., 2013). Burchinal and colleagues (2000) stated that theirs and research conducted by Deater-Deckard, Dodge, Bates, and Pettit (1998) resulted in cumulative risk indices less predictive of outcomes compared to the singular risk-factor approaches. They further stated that CRIs limit and simplify the amount of interpretable information available about the factors which, in turn, results in less precision for statistical analysis. However, they do assert that CRIs may better predict prospective developmental patterns. It is possible that statistical and descriptive information about the factors' unique effects are suppressed among the cumulative, shared variance posited on outcomes. Nevertheless, the CRI in the current study was found to uniquely predict expressive language at 36 months, suggesting potential utility in this method for ascertaining expressive language risk.

Even though the block of individual risk variables explained more variance in expressive language, only two of the individual variables – receptive language and maternal concerns – were uniquely associated with expressive language. As described, early child characteristics in children at high-risk may be predictive of language outcomes because they have an elder sibling with ASD (the genetic component), and they also display early, similar patterns of social-communicative behavior and language (broad autism phenotype), which are reliable language predictors that have often been assessed in children.

In the current study, receptive language at 12 months, but not expressive, was a robust indicator, such that it predicted expressive language at 36 months. This diverges from outcomes in other studies (Landa and Garrett-Meyer, 2006), but this result held constant across infants at high- and low-risk. Receptive language as an earlier and more significant predictor does, however, align with earlier points made about stronger comprehension than productive skills at 12 months that support concurrent abilities and can impact distal outcomes; the typical vocabulary explosion at around 18 months may then augment any differences in expressive outcomes across individuals, as suggested by these findings. Moreover, children do not have much expressive language at 12 months. Language research has probed the level of association and convergence of expressive and receptive skills over time. Landa and Garrett-Meyer (2006) examined development in a sample of children across all five domains of the MSEL at 6, 14, and 24 months. Their sample came from a larger study of siblings of children with and without ASD (N = 87), but the current study examined the children by diagnostic outcome at 24 months (ASD, language delay, or unaffected) not by risk status. They found significantly lower outcome scores on the MSEL in receptive and expressive language for children with ASD and language delay compared to unaffected children, and they found significantly lower receptive language, but not expressive language, for siblings diagnosed with ASD versus language delay, all at 24 months. The researchers posited that between 14 and 24 months, developmental delays seemingly intensified for children with ASD increasing the developmental gap in comparison to the other children. The current study also had children eventually diagnosed with ASD in the sample (*n* = 36) whose profile may possibly reflect the findings by the researchers, with the observed differences in language outcomes possibly impacted by the language of the children with ASD. It is challenging to truly compare the findings to the former study as the current study sample was older, at 36 months when expressive language ability is typically more advanced and the lexicon is larger—may differ for children with ASD—and the samples sizes are significantly different. Iverson et al. (2018) spoke to the nature of differences in findings stating that it is complex to interpret given the difficulties in measuring early, receptive language. Moreover, the lack of predictiveness of receptive language at 36 months seems to support that the effects of vocabulary explosion between 18 to 30 months and known deficits in later expressive language in the broad autism phenotype (Landa & Garrett-Meyer, 2006) results in more salient differences and effects on expressive language. At 36 months, children's expressive skills are still emerging (Rescorla, 2011), but broad social communicative skills allow them to further produce language; within group social-communicative differences may augment these differences. The outcome results do suggest that receptive and expressive language are two distinctly different dimensions of language at this developmental point, that while related do not represent the same construct in early childhood, but do typically consolidate over time.

The current study also found a significant effect for maternal concerns on language, such that concerns robustly predicted expressive language at 36 months. Concerns were also significantly correlated with expressive and receptive language at 12 months. Because mothers' concerns were predictive of language, the mothers may be doing more in the first years of life to account for perceived child needs; in turn, they may be indexing differences in language with their concerns, and consequently address this in their behavior.

Talbott and colleagues (2015b) examined mother-infant dyads (*N* = 75) from the larger study. They found that mothers of children at high-risk, not diagnosed with ASD, provided significantly more gesture input to their children at 12 months, which in turn predicted receptive and expressive language at 18, 24, and 36 months. Boin Choi and colleagues (2019)–also examining the larger study–however, did not find significant differences in maternal gesturing behavior and considered all mothers to be equally contingently and non-contingently responsive. In a separate study, Talbott et al. (2015a), with more of the infant-mother dyads (*N* = 176), found that mothers of all high-risk siblings reported more concerns. It is possible that the mothers of children at high-risk, who also had more concerns than mothers of children at low-risk, attempt to overcompensate for any early developmental differences in their interactions to improve language outcomes given their concerns (Maljaars et al., 2012) or this may be reflective of risk-status in general (Talbott et al., 2015a). Maternal behaviors can conceivably reflect concerns; and since mothers are known to be accurate reporters of their child's level of development, it is not surprising that they would not only match responsive behaviors to their child's level (Kasari, Sigman, Mundy, & Yirmiya, 1988), but attempt to advance child development by increasing frequency and level of linguistic input (Bruner, 1981). This may, in turn, have positive effects on language and augment within group differences, which Talbott et al. (2015a) reported. Research has recognized the utility of parents as reporters of their child's development and found reliability in concerns for detecting atypical development. While much of the literature has reported concerns to be predictive of ASD diagnosis, the study findings suggest that concerns may also be indicative of other developmental outcomes like language. Lo and colleagues (2017) noted that concerns are not always predictive of ASD diagnosis, with Ben-Sasson et al. (2018) extending that in examining the validity of the M-CHAT-R/F (a gold-standard early ASD screener), numerous false positives lead to diagnoses of developmental disorders and notable developmental delays. These research findings promote the examination of maternal concerns for risk of language delays, which is understudied.

In addition to the hypothesized study effects, an effect was found for the fine motor control variable on predicting expressive language outcomes. Fine motor skill may be predictive of expressive language because it is implicated in overall child development and use of language (Luyster et al., 2008). Bhat, Galloway, and Landa (2012) found that motor delays are seen as early as 3 and 6 months in siblings of children with ASD, and fine motor skills predicted expressive language at 18 months in children at high-and low-risk. In their study examining siblings of children with and without ASD, also from the larger study, Boin Choi, Leech, Tager-Flusberg, and Nelson (2018) similarly found that fine motor skill predicted expressive language scores and differentiated later diagnosis. Fine motor skill may, specifically, relate to child ability (manual dexterity) to use gesture (deictic- pointing and iconic- imitating cat whiskers on the face), which impacts language development, and therefore initiate and respond to interaction (Manwaring et al., 2017). The results from this study support these findings suggesting that it is conceivable that fine motor skill at 12 months predicted expressive language at 36 months, while interestingly gesture did not.

A number of the individual risk variables did not uniquely predict language outcomes. Expressive language at 12 months, ASD symptoms, social-communication, gesture, and maternal depressive symptoms did not predict receptive or expressive language, possibly due to the presence of the other more salient predictors. As well, the CRI did not predict receptive language, and explained only a small amount of variance in expressive language outcomes; this may possibly be due to homogeneity in the sample or additional variables that may not have been considered like a measure of mother and infant interaction. Maternal-child interaction (coding behaviors like joint attention, turn-taking, and language use) may possibly provide a more illustrative measure of the mother-child dyads to gauge how the child and maternal characteristics converge during interaction (Boin Choi et al. 2019) and, therefore, supplement the ascertainment of risk between groups if there are notable differences.

The current study also assessed the moderating effect of group assignment (low versus high-risk) on the relationship between the predictors and language outcomes. None of the interactions were significant suggesting that group assignment—or differences between infants at high- and low-risk—did not have a differential impact on the predictive effect of early risk on language outcomes. That is, whether the children were high-or low-risk did not significantly differentiate the impact of risk on language outcomes. This seems to be a particularly important result for maternal concerns, which the moderation analyses indicate have the same effects on language outcome regardless of whether mothers have an elder child with ASD.

4.3 Likelihood of ASD Diagnosis

The final exploratory aim examined the utility of both models in predicting ASD outcomes. The results suggested that both the CRI (79%) and individual risk variables (84%) were highly accurate in predicting diagnostic outcome (n_{ASD} = 36). Predicting ASD outcomes was not a primary aim of this study, and was undertaken for solely exploratory purposes to understand the possible extension of the risk indices on longitudinal outcomes. The findings are valuable in that they ultimately inform the utility of the CRI and individual risk variables on predicting likelihood that the children will be diagnosed with ASD in the sample. The effect for the CRI was fairly robust in that there was prediction of ASD diagnosis with only 36 infants in that group, importantly suggesting that risk indices may add utility in providing a parsimonious methodological approach for screening for ASD. It is possible that the CRI had such a robust effect because it is the shared variance between the predictors that is actually what determines whether children are diagnosed with ASD; that is, CRI may possibly be a latent variable model of risk for ASD more than language. This, while researchers have consistently informed of the need for early assessment and intervention, supports the extant literature that continues to explore the best methods for reliable early detection and monitoring.

Rowberry et al. (2014) also employed a prospective 12-month assessment of clinician and parent-report combined with standardized measures (like the First Year Inventory, Baranek et al., 2013) to determine likelihood of ASD diagnosis at 36 months. Additionally, they probed the degree of and differences in predictability in parents' ratings of core measures of diagnosis compared to other developmental outcomes to further inform the magnitude of the singular behaviors as more indicative of risk. They found that for infants at high-risk later diagnosed with ASD, parent and clinician ratings centrally reported atypical profiles of social-communicative skills, but not atypical sensory and motor behaviors. Their approach correctly identified 93% of the non-ASD cases and 63% of the ASD cases, which is slightly lower than the 79% accuracy for the CRI and 84% accuracy for the individual risk variables in ASD likelihood. A strength of the current approach was that it combined measurement of domains of development in addition to maternal concerns which may have augmented the accuracy in precision: Marschik, Einspieler, Garzarolli, & Prechtl (2007) approximate that nearly 7% of children who score in the bottom percentiles of parent reports develop specific language impairments (SLIs) not ASD necessarily. So, like Ben-Sasson et al. (2018) noted, parent reported concerns reliably detect developmental concerns, but diagnostic outcomes are stronger identified with additional methods like standardized assessment. These findings seemingly contribute to empirical research suggesting that this may be a promising way to assess early risk/profile as a red flag for possible ASD diagnosis in the future.

In addition to the CRI, 12-month receptive language proved to be a uniquely significant predictor of both later expressive language and ASD diagnosis. This finding is in line with the larger literature stipulating that comprehension develops earlier and faster than production, and comprehension in children with ASD is lower (Bono et al., 2004) compared to typically developing and non-ASD conditions (Landa & Garrett-Meyer, 2006). Some studies have even suggested that children with ASD, however, possess advanced expressive compared to receptive ability (Ellis Weismer, Lord, & Esler, 2010)‒which could in part explain this study finding‒that extends into later life. However, Kwok, Brown, Smyth, and Cardy (2015) examined this phenomenon in a meta-analysis of the literature and countered this theory concluding that both receptive and expressive seem to be equally deficient throughout the developmental trajectory, but it may be that some individuals with ASD possess an expressive advantage; however, this is not intrinsic to ASD. Even so, the current study found early receptive language and gesture to be unique predictors of ASD diagnosis, and this is supported in the larger ASD and socio-communication empirical literature.

Gesture was a unique predictor of ASD diagnosis, and this supports the burgeoning extant literature that has reliably found differences in gesture repertoire for children with ASD (Iverson et al., 2005, 2018; Luyster et al., 2011; Zwaigenbaum et al., 2009). Franchini et al. (2018) found that gesture predicted diagnostic outcome and did so earlier than verbal language, also measured with the MSEL. Moreover, atypical gesture is considered a criterion for ASD in the DSM-5 (Manwaring et al., 2018). Considering all this, gesture in this study and in larger ASD literature is an important indicator of ASD risk and diagnostic outcome.

As noted, gesture use can index language delays and broader developmental outcomes, like ASD (Gordon & Watson, 2015). A significant amount of empirical studies have evidenced marked early deficits in gesture repertoire in ASD and infants at high-risk. Although gesture did not predict language in this study, there is a rich literature establishing its' contribution to language development. Gordon and Watson (2015) found that gesture inventory between 13 to 15 months predicted later receptive and expressive language outcomes, positing that gesture use may be a useful marker in identifying infants who may benefit from early intervention. In a larger experimental study (Veness et al., 2012), Veness and colleagues (2014) indicated that gesture use at 12 and 24 months was the only early marker, among the other six measured by the CSBS, that discriminated the children with ASD from those with developmental delay, language impairment, and TD, highlighting its role in ASD, and relatedly their high-risk siblings. So, gesture was a robust predictor amongst others in Veness′ study, but considering that this study included additional aspects of the child profile, maternal characteristics, and compared a CRI to an additive model, it may be that at this early time point, similar to Veness, gesture is indexing broader socio-communicative concerns than language. It is also possible that the effect of gesture on expressive language was suppressed amongst other more potent predictive measures. As well, because the infants were so young, it is plausible that at this age gesture use is not a significant enough predictor of later language ability in this population, but instead evidences a marker of early and long-term social-communication overall. Nevertheless, gesture seems to be an early indicator of risk (whether ASD or communication), as supported in the larger literature (Iverson et al., 2018; Parlade & Iverson, 2015).

Given the increased likelihood of diagnosis, it seems advantageous to provide a metric for examining likelihood considering these findings support what has been stated in the literature that more singular risk factors and genetic predisposition impact future ASD diagnosis (Bedford et al., 2014; Losh et al., 2009). It does seem that the individual effect of the CRI may be bigger than the individual effects in the additive model, further supporting the benefit of cumulative risk for examining odds of diagnosis. These findings should of course be interpreted with caution given the sample size, homogeneity of the sample, and weak results for the CRI and individual risk variables in accounting for a large degree of variance in language outcomes.

4.4 Limitations and Future Directions

There are several limitations to consider for this study. First, the lack of heterogeneity within the sample regarding the dearth of educational and racial and ethnic diversity in the sample impacts generalizability of the findings. The participants may be more similarly related on the child and maternal characteristics that are known to be predictive of language, but show greater differences in heterogeneous populations (Hart & Risley, 1995; Kurstjens & Wolke, 2001). Second, the sample size (N = 173) was underpowered for moderation and logistic analyses, to draw strong conclusions from the examination of ASD and potential for differential effects of group assignment on language outcomes. However, the sample size is a relatively normal size representative of the larger child developmental empirical literature where attrition and compliance are especially difficult to ensure in family-centered studies, and was suitable for the primary aim of examining the CRI versus individual risk models of the study. Third, the primary intention of the study was to examine infants at high-risk; children at high-risk were oversampled possibly leading to sample specific results that may challenge the possibility of extending these results outside of the sample when using this specific CRI to assess language outcome risks in other children (e.g., typically developing or Down syndrome).

Future research should consider the use of CRIs to further examine methods of more parsimonious assessments of risk to target individuals with heightened risk of language development, and most ideally couple this with empirically-based intervention. Researchers may aim to replicate the CRI with a larger and more ethnically and racially diverse sample, if possible. Additionally, using either the current CRI or a more refined version with more maternal characteristics (e.g., maternal education and responsivity) and child interactive measures (e.g., turn-taking and joint attention) may increase generalizability and further interpretation of findings. Researchers may increase the predictiveness of the CRI by testing it without variables unrelated to diagnosis like maternal depressive symptoms. Considering two CRIs, one for language and one for ASD, may help to tease apart the factors that seem to be driving language and ASD, separately, to extend its utility across contexts (e.g., research settings and clinical practice). This should inform our understanding of how factors may singularly and cumulatively augment risk on outcomes for children at high-risk. It would be noteworthy to determine if these results remain stable over time (e.g., to seven years of age). Finally, if the assessed measures are more highly correlated in future samples, risk may be considered as a latent variable to manage multicollinearity, which was not an issue in this study.

4.5 Conclusion

Despite the limitations, the current study adds to the broader literature in language development, cumulative and multi-risk, ASD, high-risk infant siblings, and assessment of child development by undertaking a novel approach to the examination of risk in infancy. Moreover, the longitudinal aspect of this research is particularly important as researchers continue to learn about the singular and cumulative impact of early features of development on later outcomes. In conclusion, this study found that risk at 12 months was predictive of receptive and expressive language at 36 months and resulted in increased likelihood of an ASD diagnosis at 36 months. A number of the individual risk variables, along with the CRI, were significant, unique predictors of risk. Interestingly, maternal concerns and receptive language at 12 months seemed to be particularly potent predictors of expressive language at 36 months, in the presence of developmental control variables across the groups. These findings suggest that the early examination of multiple facets of child and maternal characteristics are contributory in assessing later risk, and this serves a purpose in providing a stronger case for early intervention to positively impact the developmental trajectory. Furthermore, high-risk siblings of children with ASD display increased cumulative risk in early developmental domains including receptive and expressive language, behavior, social-communication, gesture, maternal depression, and self-reported maternal concerns that may index prospective language outcomes.

4.6 Implications

Cumulative risk indices have been used far and wide to examine the collective magnitude of singular risk factors effect on outcomes related to child development, largely cognitive and social-emotional development (Evans et al., 2013; Wade et al., 2016; Wade, Moore, Astington, Frampton, & Jenkins, 2014). This seems to be the first study with a relatively normal sample size to: 1) cultivate a CRI comprised of established, consequential maternal and child characteristics via standardized assessment, 2) develop a CRI to predict language delay in a sample of infants at high- and low-risk at 12 months, some who were also diagnosed with ASD, and 3) utilize a CRI of child and maternal characteristics to examine likelihood of ASD diagnosis, all of which were conducted on longitudinal measures. The findings suggest that this is a valuable area of study as it has not before been done. If reliability and validity can be established in cultivating a parsimonious risk index, then this may be a worthwhile approach to additionally detect and intervene in early language development.

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Appendix: Missing Data

Variable	*N*	%	*M*	*SD*
Sex	0	0		
Group Assignment	0	0		
Diagnostic Outcome	4	2.3		
MSEL_12_r	3	1.7%	44.41	8.16
MSEL_12_e	3	1.7%	47.10	9.27
MSEL_12_f	3	1.7%	59.22	9.66
MSEL_12_g	6	1.7%	42.53	10.24
AOSI	25	14.5%	3.56	2.82
CSBS	40	23.1%	62.53	17.23
CDI	68	39.3%	19.21	8.92
CESD	58	33.5%	9.32	9.74
Concern	89	51.4%		
MSEL_36_r	3	1.7%	55.07	10.08
MSEL_36_e	4	2.3%	57.21	9.35
Maternal Education	26	15%		
Baby Race	4	2.3%		
Maternal Race	4	2.3%		

Note. N = 173. Msel = Mullen Scales of Early Learning: r = receptive, e = expressive, f = fine motor, g = gross motor; MSEL_12 = Mullen Scales of Early Learning measured at 12 months; MSEL_36 = Mullen Scales of Early Learning measured at 36 months; AOSI = Autism Observation Scale for Infants; CSBS = Communication and Symbolic Behavior Scales; CDI = Mac-Arthur Bates Communicative Development Inventories; CESD-R = Center for Epidemiologic Studies Depression-Revised.